NEWFOUNDLAND AND LABRADOR

DEPARTMENT OF ENVIRONMENT

HYDROGEOLOGY
OF
THE AVALON PENINSULA AREA

by

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ABSTRACT

The Newfoundland and Labrador Department of Environment has commissioned a series of regional studies to document the existing hydrogeological data base and groundwater potential, with reference to the surficial and bedrock geology, of selected areas on the Island of Newfoundland. This study, the sixth in the overall series, describes the hydrogeology of the Avalon Peninsula area, excluding the Trinity Bay Area.

This study is based primarily on existing data sources with limited field checking. The surficial geology map (Map No. 1) is based on that of Henderson (1972), but surficial geology discussions reflect current thinking and terminology. The bedrock geology map (Map No. 2) represents the most current work on the Avalon area and the extensive discussion of the geology of the Avalon provides a framework for future studies. Provincial water well records, supplemented by aquifer test data, were used to subdivide the surficial deposits into two hydrostratigraphic units and to identify five bedrock hydrostratigraphic units (Map No. 3). Comparison of well depths with well yields showed a general trend of decreasing well yield with increasing well depth. Hence drilling deeper wells does not increase the probability of obtaining higher well yields.

Streamflow and water level data were analyzed to determine groundwater discharge as reflected in the baseflow component of total streamflow for given drainage basins. Based on the observed strong correlation between groundwater stage and stream discharge, it was estimated that groundwater contribution to streamflow may be in the order of 20 to 25 percent. The rapid response of groundwater levels to rainfall indicates the relative vulnerability of dug wells to dry periods.

Surface waters are characterized by very low total dissolved solids, less than 25mg/L, pH values between 4 and 6.5 and average alkalinity and hardness values of less than 10 mg/L. The low pH and alkalinity values suggest that these waters could be very susceptible to the effects of acidic precipitation.

Chemical analyses of available water samples from both dug wells in overburden and drilled bedrock wells provided the basis for an assessment of groundwater quality. Three generic groundwater groups, calcium bicarbonate, sodium bicarbonate, and a very soft, acidic, low alkalinity water, were identified from the groundwater chemistry data. Water quality problems were identified by about 50 percent of the analyses and were related mostly to high manganese concentrations associated with high iron values and in a few cases with elevated chloride values.

TABLE OF CONTENTS

ABSTRACT ii

LIST OF FIGURES vii

LIST OF TABLES ix

NOMENCLATURE AND CONVERSION UNITS x

1. INTRODUCTION..... 1

1.1 Purpose and Scope of Investigation..... 1

1.2 General Description of the Area..... 3

1.2.1 Location..... 3

1.2.2 Physiography and Drainage..... 3

1.2.3 Population and Economy..... 7

1.2.4 Climate..... 8

1.3 Previous Work..... 14

1.4 Acknowledgements..... 15

2. GEOLOGY..... 17

2.1 Surficial Geology..... 17

2.1.1 Sources of Information..... 17

2.1.2 Terminology..... 17

2.1.3 Preglacial Landscape..... 19

2.1.4 Glacial History..... 21

2.1.5 Unconsolidated Sediments..... 23

2.2 Bedrock Geology..... 30

2.2.1 Introduction..... 30

2.2.2 General Geological Setting..... 33

2.2.3 Avalon Zone Facies Analysis and Facies

Models..... 36
Late Riphean to Vendian Subaerial and
Marine Volcanism..... 36
Vendian Marine Sedimentation 39
Vendian Fluvial Sedimentation..... 44
Cambro-Ordovician Sedimentation and
Volcanism 47
Vendian and Paleozoic Magmatism..... 52
2.2.4 Structure and Metamorphism..... 54
Avalonian and Acadian Orogenesis..... 54
Unconformities..... 55
Folds..... 56
Joints..... 58
Faults..... 59
2.2.5 Paleogeographic Evolution 60
Regional Tectonic Environments..... 60
Evolution of the Avalon Peninsula..... 62

3. HYDROGEOLOGY..... 64
3.1 Introduction..... 64
3.1.1 Sources of Data..... 68
3.1.2 Depth and Yield of Bedrock Wells..... 70
3.1.3 Aquifer Tests..... 86
3.2 Hydrostratigraphic Units..... 89
3.2.1 Surficial Deposit Hydrostratigraphic Units.. 90
Hydrostratigraphic Unit-S1..... 91
Hydrostratigraphic Unit-S2..... 92

3.2.2 Bedrock Hydrostratigraphic Units..... 92
3.3 Groundwater Flow Systems..... 98

4. SURFACE WATER - GROUNDWATER HYDROLOGY..... 100
4.1 Hydrologic Budget..... 100
4.1.1 Precipitation..... 101
4.1.2 Runoff..... 101
4.2 Groundwater Discharge to Streams..... 106
4.3 Evapotranspiration..... 112

5. WATER QUALITY..... 113
5.1 Surface Water Quality..... 113
5.2 Groundwater Quality..... 114
5.3 Overburden Groundwater Quality..... 118
5.4 Bedrock Groundwater Quality..... 119

6. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS..... 129

REFERENCES 134

APPENDIX A - Census Data..... A-1
APPENDIX B - Water Well Records.....B-1

LIST OF FIGURES

1.1 Location map, cross-hatching indicates study area..... 4

1.2 Topography and drainage of Avalon Peninsula..... 5

1.3 Location of climatic stations 10

2.1 Geological map of the Avalon Zone of Newfoundland. The index map shows the principal tectonostratigraphic zones of the Newfoundland Appalachians..... 31

2.2 Geological Map of the Avalon Peninsula..... 35

2.3 Stratigraphic section of Eastern Avalon Peninsula..... 40

2.4 Geological map of the Cappahayden - Ferryland area..... 42

2.5 Geology of St. John's and vicinity..... 46

2.6 Geology of the Flat Rock area..... 57

3.1 Conceptual model of the main flow paths in fractured rocks. 65

3.2 Cross section with regularly fractured rock forming outcrops and the more fractured and hence more permeable bedrock forming depressions filled by surficial materials..... 67

3.3 Frequency histograms for well depths and well yields for each bedrock grouping 74

3.4 Relationship between well depth and well yield for four of the major bedrock groupings..... 82

3.5 Distribution of main deposits of surficial hydrostratigraphic unit S2 93

3.6 Distribution of bedrock hydrostratigraphic units. Description of each unit is given in Table 3.6..... 97

4.1 Location of hydrometric stations (solid dots) and outline of selected drainage basins (cross-hatching).. 102

4.2 Mean monthly yields for representative basins, Avalon Peninsula 105

4.3 Daily stream discharge for 1981, Waterford River at Kilbride, showing separation of groundwater component of flow..... 107

4.4 Daily stream discharge for 1981, Rocky River at Colinet, showing separation of groundwater component of flow 109

5.1 Location of wells sampled for water quality analysis and aquifer test locations 116

5.2 Histograms of significant chemical species in both bedrock and overburden wells 123

5.3 Graph showing number of unacceptable results of several parameters versus total number of available analyses (Table 5.1)..... 126

LIST OF TABLES

1.1 Monthly mean daily temperatures (°C) 11

1.2 Mean monthly total precipitation (mm) 12

1.3 Evapotranspiration and lake evaporation (mm) 13

2.1 Classification of glaciogenic sediments and landforms appropriate for the island of Newfoundland (omitting active glacier features). 18

2.2 Facies classification of diamicton and related sediments. 20

3.1 Data for wells completed in overburden material, by district and community 71

3.2 Distribution of wells in terms of bedrock units..... 73

3.3 Raw statistics for well depth and well yield for selected rock units 80

3.4 Aquifer test data 87

3.5 Surficial deposit hydrostratigraphic units 94

3.6 Bedrock hydrostratigraphic units 96

4.1 Summary of basin yield data, Avalon Peninsula 103

4.2 Results of baseflow separation and evaluation of hydrologic budget parameters for Waterford River and Rocky River Basins for years 1977 and 1981 110

5.1 Summary of water quality data (in pocket)

NOMENCLATURE AND CONVERSION UNITS

^{o}C	-	degrees Celsius
dm^3	-	discharge in cubic metres
epm	-	equivalent parts per million
ft	-	feet x 0.3048 = metre
gpm	-	gallons per minute x 4.55 = L/min
km	-	kilometre x 0.6214 = mile
km^2	-	square kilometre x 0.3861 = square miles
L/min		
Lpm	-	litre per minute x 0.220 = gpm
m	-	metre x 3.28 = feet
ma	-	million years
mg/L	-	milligrams per litre
mm	-	millimetre x 0.0394 = inches
m^3/s	-	cubic metre per second x 35.34 = ft^3/s
T.D.S.	-	total dissolved solids
+ve	-	positive
-ve	-	negative

1. INTRODUCTION

An adequate supply of water is essential to the industrial, recreational and domestic needs of modern society. In Newfoundland, surface waters are generally adequate to supply the fresh water needs of most towns. In the absence of a suitable surface supply, small communities and individual users have to rely on groundwater from dug or bored wells. To determine the extent to which groundwater is an alternate source of supply, and the availability and quality of this supply, the Newfoundland and Labrador Department of the Environment undertook to prepare a series of reports, on a reconnaissance scale, of the hydrogeologic characteristics of selected areas within the province. This report on the hydrogeologic characteristics of the Avalon Peninsula Area is the sixth in this series of reports designed to document the current data base and understanding of the groundwater system in Newfoundland, and hence provide the basis for effective management and protection of the available water resources.

1.1 Purpose and Scope of Investigation

This hydrogeological study of the Avalon Peninsula area has followed the guidelines provided by the Water Resources Division, Department of Environment. The objectives of this

study were to determine the physical characteristics of the major geological units in relation to the occurrence, availability and quality of the constituent groundwater and to characterize the major geologic units in terms of aquifer potential. The data base available to the study included published and unpublished reports on the geology of the area, existing water well data, and hydrogeologic data from government and private agencies. Aerial photographs were used to supplement the data base in selected areas.

A surficial geology map, based on that by Henderson (1972), was used to determine the role of surficial geology in defining the hydrogeologic characteristics of the area. In addition, a bedrock geology map was compiled on a scale of 1:250,000. This map was used as the basis for discussing the structure and hydrogeological characteristics of the bedrock formations as well as the basis for combining the various rock groups in hydrostratigraphic units.

Stream flow and precipitation records were used to assess the groundwater contribution to stream flow and the annual rate of groundwater recharge from precipitation. Existing surface water and groundwater quality data provided the basis for assessing the chemical character of the groundwater resources of the Avalon Peninsula.

1.2 General Description of the Area.

1.2.1 Location

The Avalon Peninsula study area forms the easternmost part of the Island of Newfoundland (Fig. 1.1). The study area is bounded by all the coastline between the 47° 30' North latitude line on the Isthmus of the Avalon in Placentia Bay around the Avalon Peninsula in an anticlockwise direction to Georgetown on the west side of Conception. Inland the boundary continues westward from Conception Bay along the 47° 30' North latitude line until it intercepts the eastern coastline of Placentia Bay.

1.2.2 Physiography and Drainage.

The physiography of the Avalon Peninsula study area has been described in a number of studies . These include the paper by Twenhofel and MacClintock (1940) on the physiography of the Island of Newfoundland, studies by McCartney (1954, 1967), Henderson (1972), Bruckner (1979), Williams and King (1979) and Heringa (1981). The description of the physiography and drainage given in this report follows that of Heringa (1981).

Figure 1.2, taken from Heringa (1981), shows the

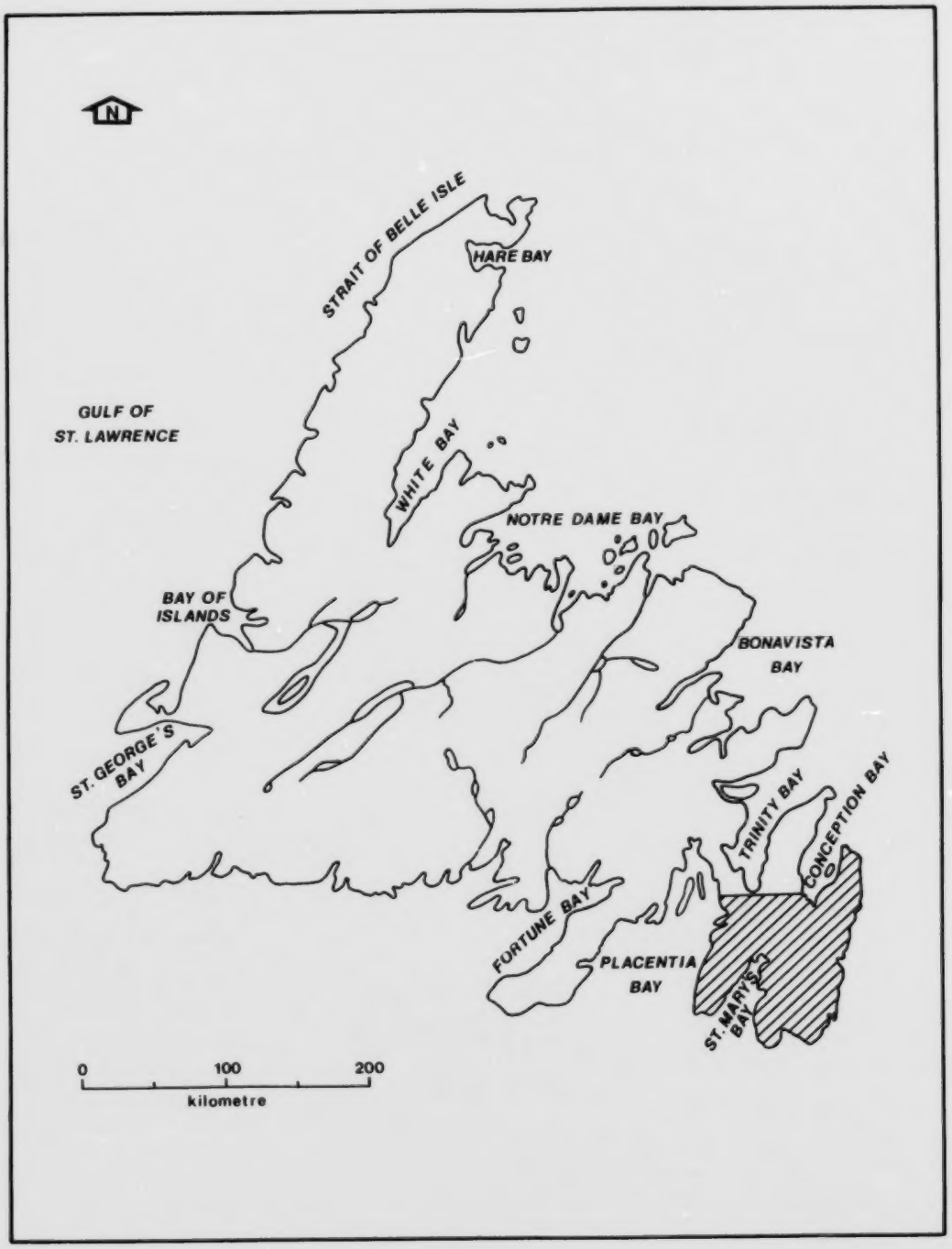

Figure 1.1 Location map, cross-hatching indicates study area.

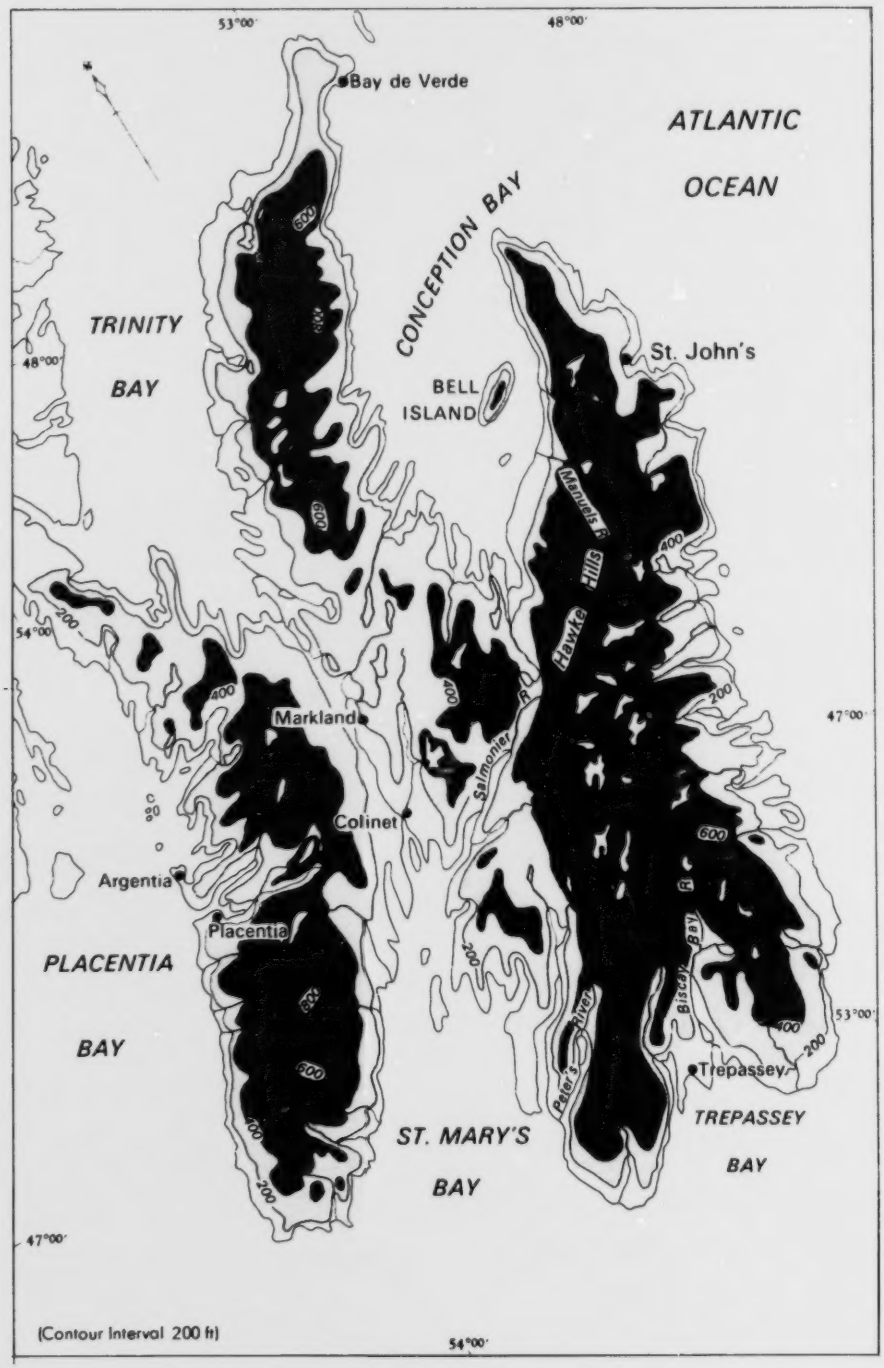

Figure 1.2 Topography and drainage of Avalon Peninsula (Heringa, 1981).

north-south trending highland areas, on both the western and eastern sides of the study area, paralleling the central lowland area that extends between Conception Bay and St. Mary's Bay. The northwestern part of the study area is characterized by barren, irregular and rough topography with numerous outcrops and several areas of peat accumulation. Elevations are generally 60 - 120 m above sea level with a few areas rising to about 200 m. However in the southwestern part of the area elevations of 300 m are common but the topography is more gentle. The coastline between Placentia Bay and the southern parts of St. Mary's Bay is characterized by steep cliffs, 30 - 60 m in height. The central lowland area between Conception Bay and St. Mary's Bay has gentle relief, barren uplands rising up to 315 m above sea level and is dotted with numerous small lakes. The southeast part of Conception Bay is characterized by a relatively smooth coastal plain. By contrast the east side of the study area is characterized by a steep and rugged coastline from Cape St. Francis to Renews. The southeastern part of the area is characterized by a barren but rolling surface and more moderate coastline. Both the southeastern and southwestern parts of the study area are characterized by extensive bog and marsh deposits.

The main rivers draining the Avalon Peninsula are shown on Figure 1.2. These include Crossing Place, Manuels,

Northeast, Rocky, Salmonier, and Southeast Rivers. Additional drainage is provided by numerous small streams. As with most of Newfoundland, the study area is dotted with lakes, covering 9 percent (Heringa, 1981) of the surface of the Peninsula, providing the storage capacity for a number of small hydro-electric generating stations.

1.2.3 Population and Economy

Census data for 1981 (Newfoundland Statistics Agency) for the Avalon Peninsula Study area indicate a population of approximately 193,129 located in some 103 incorporated and unincorporated communities. The area includes parts of 17 electoral districts; Bellevue, Conception Bay South, Ferryland, Harbour Main - Bell Island, Kilbride, Mount Pearl, Mount Scio, Placentia, Port de Grave, St. John's Center, St. John's East, St. John's East Extern, St. John's North, St. John's South, St. John's West, St. Mary's - the Capes and Waterford-Kenmount Districts.

Approximately 68 percent of this poulation is distributed in the centres of St. John's (83,770), St. John's Area (24,485), Mount Pearl (11,543),and Conception Bay South (10,856). Other larger communities include Wabana (4,254), Goulds (4,242), and Torbay (3,394). The remainder of the population is distributed in smaller communities which range

in population size from less than 100 to less than 3000 people (refer to Appendix A for a more complete list of those communities within the study area). Most of the larger centres are located on the eastern part of the peninsula. In almost all cases, both the large and small population centres are located along the coast.

Economic activity within the study area is based on the inshore and offshore fishery, supplying fishing fleets and ship repair work. Mining activities include pyrophyllite mining at Manuels, and quartzite quarrying operations near Long Harbour. Industrial activities include an oil refinery (no longer operating) and supply centre at Holyrood, peat operations in the southern Avalon, light industry in the Donovan's and Conception Bay area, minor forest activity, and 50 megawatts (Heringa, 1981) of installed hydro-electric capacity. St. John's contains major education and government centres plus the entire Avalon is showing an increase in tourism activity. Major future activity at selected centres may well be in servicing and supplying the offshore oil and gas industry. This later activity may make strong demands on the water resources of the Avalon Peninsula.

1.2.4. Climate

The climate of the Avalon Peninsula study area is

dominated by the Labrador Current which consists primarily of arctic waters. This current introduces relatively cold water to the area in spring and summer, but by comparison fairly warm water in winter. Hence the study area has a marine climate, characterized by short but pleasant summers and mild winters. Monthly averages for the daily temperatures from 16 climatic stations (Fig. 1.3) are given in Table 1.1. The average temperature for the warmest month (August) varies from 13.4°C to 16.7°C over the study area, with the central part of the area being warmest and the coastal areas coolest. February is the coldest month with average temperatures ranging from -4.5°C to -1.9°C.

Table 1.2 shows the average monthly precipitation, in mm, for 20 stations (Fig. 1.3). Precipitation, while fairly evenly distributed throughout the year, is heaviest during the winter months with May to September being the months with the lowest precipitation.

In order to estimate the proportion of precipitation that is available for direct runoff or recharge one must attempt to estimate the amount of moisture lost to the atmosphere by evaporation. Evapotranspiration data have been calculated by Environment Canada for Argentia Airport, Seal Cove and St. John's Airport (Table 1.3). In addition lake evaporation data, based on evaporation pan measurements for

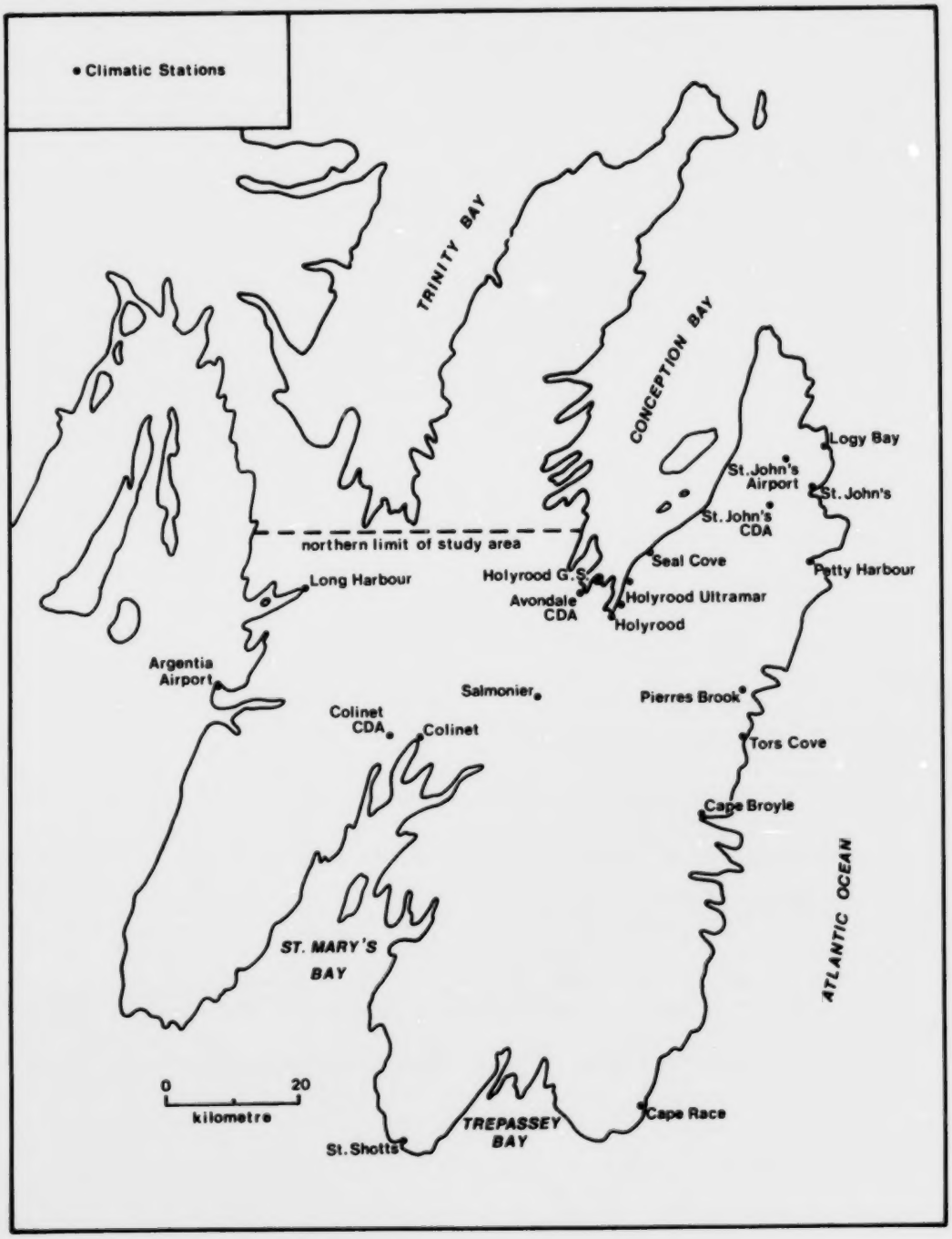

Figure 1.3 Location of climatic stations.

Table 1.1 Monthly mean daily temperatures (°C) (Environment Canada, 1981).

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual	Duration
Argentia Airport	-1.5	-1.9	-0.5	2.3	5.6	9.7	14.0	15.3	12.5	8.4	5.0	0.3	5.8	*
Avondale CDA	m	m	m	m	m	11.1	15.4	15.5	11.9	7.3	m	m	m	*
Cape Race (AUT)	-2.9	-3.6	-1.7	0.9	3.9	8.1	12.0	13.4	11.0	7.1	3.8	-0.3	4.3	*
Colinet	-3.4	-3.8	-1.3	2.4	6.0	10.1	14.3	15.3	11.8	7.4	3.9	-1.1	5.1	1951-1980
Colinet Peat Bog CDA	m	m	m	m	5.2	10.0	14.3	15.1	11.7	7.4	m	m	m	*
Holyrood	-3.3	-4.2	-2.0	1.2	5.1	10.2	15.0	14.9	11.1	7.0	3.4	-1.0	4.8	*
Holyrood Gen Stn.	-2.2	-2.9	-0.7	2.7	6.6	11.7	16.3	16.7	13.1	8.7	4.6	0.1	6.2	*
Holyrood Ultramar	-2.3	-2.8	-0.7	3.0	6.9	11.9	16.5	16.7	13.0	8.6	4.9	0.1	6.3	*
Logy Bay	-2.9	-3.6	-1.6	1.7	5.7	11.1	15.5	16.1	12.3	7.9	4.0	-0.6	5.5	*
Long Harbour	-2.6	-3.3	-1.0	2.6	6.2	10.4	14.9	15.7	12.9	8.6	4.7	-0.2	5.7	*
St. John's	-3.5	-4.0	-1.7	2.0	6.3	11.6	16.1	16.0	12.2	7.6	3.8	-1.0	5.5	*
St. John's Airport	-3.9	-4.5	-2.3	1.2	5.4	10.9	15.5	15.3	11.6	6.9	3.4	-1.5	4.8	1951-1980
St. John's West CDA	-3.8	-4.3	-2.0	1.6	5.8	11.1	15.6	15.5	11.6	7.1	3.5	-1.4	5.0	1951-1980
St. Shotts	-2.1	-2.5	-1.6	1.4	4.7	7.8	12.3	14.1	11.7	7.7	4.3	-0.3	4.8	*
Salmonier	-4.1	-4.1	-1.9	1.7	6.0	10.8	15.4	15.4	12.1	7.5	3.9	-1.1	5.1	*
Seal Cove	-2.9	-3.1	-0.8	2.9	6.9	12.1	16.6	16.5	12.7	8.1	4.4	-0.5	6.1	*

m missing

* adjusted normals based on 5 to 19 years inclusive from 1951 to 1980 and any other available data from 1931 to 1950.

Table 1.2 Mean monthly total precipitation (mm) (Environment Canada, 1981).

STATION	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	MEAN ANNUAL	DURATION
Argentia Airport	113.9	106.2	70.6	77.3	67.4	74.7	72.7	96.2	83.5	89.6	105.4	110.4	1067.9	*
Avondale CDA	m	m	m	m	75.7	77.4	76.5	113.0	110.1	125.2	m	m	m	*
Cape Broyle	154.5	135.3	136.0	118.1	102.2	81.8	85.6	115.5	123.6	149.3	159.1	160.7	1521.7	**
Cape Race (AUT)	138.6	107.3	95.9	106.9	106.9	80.5	84.9	140.3	104.3	137.9	146.3	129.2	1379.0	*
Colinet	138.2	119.9	110.5	99.7	95.5	101.0	97.3	124.5	115.2	132.3	153.7	144.3	1431.8	***
Colinet Peat Bog CDA	m	m	m	m	121.5	97.6	97.9	126.9	114.2	138.9	m	m	m	*
Holyrood	131.4	91.8	93.3	66.7	56.1	60.5	46.7	83.7	82.0	102.6	117.0	97.1	1028.9	*
Holyrood Gen. Station	109.7	90.9	113.2	70.9	65.5	63.7	59.6	93.1	79.8	92.2	124.0	112.5	1075.1	*
Holyrood Ultramar	126.5	97.6	97.2	78.4	73.0	65.3	54.7	97.4	76.7	118.4	105.8	92.9	1083.9	*
Logy Bay	73.6	68.8	87.9	67.1	66.6	68.1	64.0	74.3	52.2	102.4	108.2	78.9	912.1	*
Long Harbour	124.1	114.3	115.6	79.5	95.9	87.6	75.9	113.2	106.4	152.7	134.5	121.7	1321.4	*
Petty Harbour	138.0	121.6	122.3	102.8	99.4	72.9	70.2	117.8	110.8	147.6	164.1	152.7	1420.2	*
Pierres Brook	147.2	137.9	118.1	121.6	106.8	80.7	75.4	120.0	115.1	142.8	161.5	156.4	1483.5	*
St. John's	164.8	141.4	131.2	108.5	95.7	70.5	60.6	105.7	101.0	135.9	146.9	158.3	1420.5	*
St. John's Airport	155.8	140.1	131.9	115.6	101.8	85.6	75.3	121.6	116.7	145.5	162.5	161.2	1513.6	1951-1980
St. John's West CDA	180.8	166.2	150.5	126.2	106.8	79.8	73.8	114.7	106.4	145.3	167.8	176.4	1594.7	1951-1980
St. Shotts	139.5	103.1	131.3	122.9	110.2	106.3	104.2	112.1	132.5	129.6	136.8	124.7	1453.2	*
Salmonier	136.8	130.7	114.4	95.2	102.5	88.6	86.9	124.3	125.2	140.6	128.4	151.2	1424.8	*
Seal Cove	137.3	124.6	121.2	95.4	75.9	73.6	65.7	100.1	93.2	128.8	121.2	135.9	1272.9	*
Tors Cove	128.4	128.7	117.4	106.7	97.1	73.1	78.4	112.0	113.7	140.7	152.3	141.6	1390.1	**

m missing
* adjusted normals based on 5 to 19 years inclusive, from 1951 to 1980 and any other available data from 1931 to 1950.
** 20 to 24 years
*** 25 to 29 years

Table 1.3 Evapotranspiration and lake evaporation (mm) (Nolan, Davis and Associates Limited, 1982).

STATION	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Argentia Airport													
Potential	0	0	0	17	50	80	111	112	80	50	30	6	535
Actual	0	0	0	17	50	80	105	100	80	50	30	6	517
Seal Cove													
Potential	0	0	0	17	50	91	122	112	72	43	24	0	529
Actual	0	0	0	17	50	88	101	111	72	43	24	0	505
St. John's Airport													
Potential	0	0	0	9	50	80	122	112	80	43	24	0	518
Actual	0	0	0	9	50	80	115	112	80	43	24	0	512
Mean Calculated Lake Evaporation	-	-	-	-	-	100.4	126.8	96.8	79.3	-	-	-	

Note: Potential and actual evaporation calculations assume 100mm of soil moisture.

the St. John's Airport, are also presented in Table 1.3. Given the considerable spatial variability in evaporation rates as well as their sensitivity to changes in ground conditions (vegetation, drainage, etc.) the data in Table 1.3 must be used carefully when one attempts to determine the components of a water budget.

1.3 Previous Work

Previous hydrogeologic studies include parts of a major study carried out by Shawinigan Engineering Company Limited and James F. MacLaren Ltd. entitled "Water Resources Study of the Province of Newfoundland and Labrador" for the Atlantic Development Board (Shawinigan and MacLaren, 1968). This report provides a general overview plus detailed studies of parts of the Avalon Peninsula.

The hydrogeology of the northern part of the Avalon Peninsula has been described in Water Resources Report 2-4, "Hydrogeology of Trinity Bay Area" (Nolan, Davis and Associates Ltd., 1982). Other reports include "Water Well Data for Newfoundland, 1950-1977", produced by the Newfoundland Department of the Environment, "Soils of the Avalon Peninsula, Newfoundland" (Heringa, 1981), and "Surficial Geology of the Avalon Peninsula, Newfoundland (Henderson, 1972). Other studies are discussed within the

appropriate sections of this report.

1.4 Acknowledgements

This study was conducted under the direction of J.E. Gale. The surficial geology section of this report was prepared by R.J. Rogerson, the bedrock geology by A.F. King, the hydrology and geochemistry by R.M. Francis and the hydrogeology and remaining sections by J.E. Gale. The bedrock geology map represents the culmination of about fourteen years of field work, by King, that was supported by Natural Science and Engineering Research Council of Canada Grants.

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2. GEOLOGY

2.1 Surficial Geology

2.1.1 Sources of information

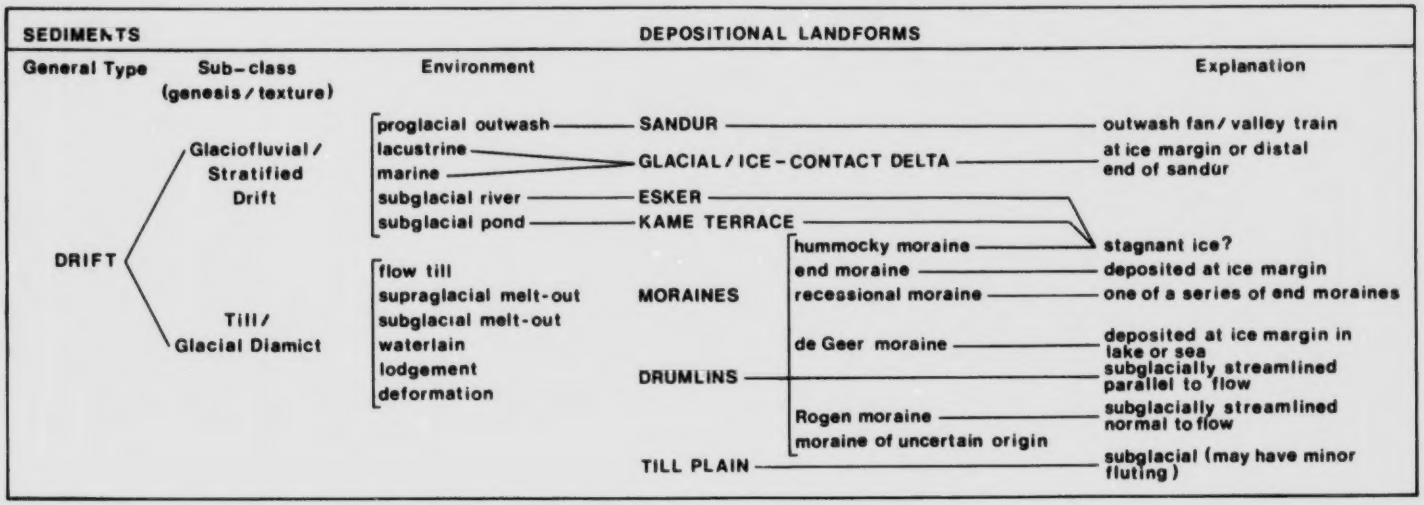
Henderson's (1972) map and memoir on the surficial geology of the Avalon Peninsula are the major sources of imformation. This is supplemented by papers by Batterson, 1983; Bruckner, 1969; Eyles and Slatt, 1977; Grant, 1974; MacClintock and Twenhofel, 1940; Macpherson, 1981; Rogerson, 1974, 1982; Rogerson and Tucker, 1972; Slatt, 1972; Tucker, 1976; plus general unpublished observations by Rogerson on the glacial geology of the area.

2.1.2 Terminology

A major problem in preparing this section is that terminology in the literature is not standardized. Henderson (1972) and others use many terms, which are no longer current, to describe sediments and landforms that should be avoided. In this report, terms for till are those recommended by Boulton (1980) while the term moraine and its variants are used to describe landforms only as recommended by Sugden and John, 1976. Table 2.1 will clarify the usage.

In all future investigations where original data is to

Table 2.1 Classification of glaciogenic sediments and landforms appropriate for the island of Newfoundland (omitting active glacier features).



be collected, drift should be described in facies terms, as recommended by Martin (1980). This classification provides textural information for economic use and allows for reinterpretation of genesis to occur independent of these considerations. Table 2.2 summarizes the classification.

2.1.3 Preglacial landscape

The Avalon Peninsula has been subaerial since at least the Mesozoic. During Mesozoic and early Cenozoic times subaerial denudation reduced the varied terrane of the Avalon to one or more level plainlands, variously called Peneplains or Pediments (Rogerson 1981). The dominant surface has been called the Lawrence Peneplain (Twenhofel and MacClintock, 1940) and ranges in elevation from over 100 to almost 200 m above sea level. It is particularly well-developed on the barrens of the southern Avalon between Cappahayden and Peter's River. A number of resistant residual hills or Monadnocks such as Butterpot, Red Hill, Triangle Peak, and Watch Hill rise above these level surfaces to a general maximum elevation of 300 m.

Preglacial drainage patterns were probably simple, consisting of streams which radiated outwards from the bulk of the Southern Avalon and formed a dendritic pattern still evidenced in the drowned inlets of St. Mary's Bay. Drainage

Table 2.2 Facies classification of diamicton and related sediments (Martin, 1980).

TYPE		GRAIN SIZE (see notes)	T1	T2	EXTERNAL CONTACTS	INTERNAL STRUCTURE	GEOMETRY
MATRIX - SUPPORTED DIAMICTON FACIES							
Dm 1	massive facies 1	mG/gM. Max. clast size up to boulder. Matrix silty clay to sandy silt. Homogeneous, or minor sand lenses.	0.5 10	- -	U: sharp irregular or erosive L: erosive irregular (commonly overlies rockhead)	Stiff, compact, with rare inclined shear planes. Structureless or indistinct clast long-axis orientation. Clasts sub-angular to well-rounded; some striated.	Sheet/sheet drape p1>100?
Dm 2	massive facies 2	mG/gM. Max. clast size up to cobble. Matrix silty clay to sandy silt.	1 2	- -	U: not seen or sharp undulatory L: sharp planar or undulatory undulatory with local erosion	Soft on initial exposure. Commonly badly weathered. Random clast orientation. Clasts sub-angular to well-rounded. Some striated. Rare deformed lenses. Normal faults below base.	Sheet/sheet drape p1>50?
Dsi	stratified isolated	mG/gM. Max. clast size up to boulder. Matrix sandy clayey silt.	0.1 1.5	- -	U: sharp irregular L: sharp or erosive undulating	Soft on initial exposure. Irregular sand lenses and stringers. Clasts sub-angular to well-rounded, may overlie thin gravel-free unit. Striated clasts seen.	Sheet drape,wedge or lens p1<50
Dsm	stratified multiple	mG/gM. Max. clast size up to v.c. gravel. Matrix silty clay to sandy silt. Interbedded with thin units of clay/silt/sand.	0.1 4.0	0.02 0.5	U: gradational interbedded or sharp irregular L: gradational interbedded or sharp planar	Parallel undulatory or irregular bedding. Common small-scale overturned folds and normal faults. Beds sharp-based, rarely normal or inverse clast-graded. Sharp upper contacts. Striated clasts not seen.	Sheet/sheet drape p1 20 - 100 p2 10 - 50
Dsr	stratified reworked	Matrix med/coarse sand.	0.05 0.01	0.05 0.1	U: sharp planar or gradational L: sharp planar or gradational	Close-packed angular to rounded clasts of mud and diamicton.	Wedge p1<50
MATRIX - RICH FACIES							
Gr	matrix-rich gravel.	msG. Max. clast size cobble gravel. Matrix clayey silty sand to silty sand.	0.3 2	- -	U: sharp undulatory or gradational L: sharp undulatory or planar planar	Structureless, or indistinct subhorizontal clast-orientation (rare imbrication). Clasts rounded to sub-angular. Diamicton clasts and lenses common.	Sheet/basin fill p1 10 - 50
B	boulder gravel	G. Max. clast size large boulder. Subordinate muddy sand matrix.	1 15	- -	U: sharp irregular L: sharp irregular	Structureless, or highly deformed (normal faults). Rounded to sub-angular clasts.	Sheet, wedge or lens p1 10 - 50
Gb	breccia	G/MsG. Max. clast size up to boulder. Subordinate muddy sand matrix.	0.5 2.0	- -	U: sharp planar or irregular or gradational L: sharp planar/irregular	Angular clasts, subhorizontal or imbricated clast-fabric. Openwork, some secondary matrix development.	Wedge p1 5 - 20

Notes T1 overall thickness range (m)
T2 bed thickness range (m)
p1 overall length/height ratio
p2 bed length/height ratio

G = gravel
mG = muddy gravel
msG = muddy sandy gravel
gM = gravelly mud

(Folk et al., 1970)

Modal clast sizes are quoted.

into Conception Bay may have shown a greater degree of structural control with parallel streams following fault-bounded valleys. All rivers on the Avalon are short headwater streams, formerly the tributaries to the major streams which occupied St. Mary's Bay, Trepassey Bay, the Avalon Channel and Conception Bay during periods of lower relative sea level. The shortage of subaerial alluvial sections to rivers on the Avalon is explained partly by the general rise of sea level during the late Cenozoic and most recently during the Holocene.

2.1.4 Glacial History

The glacial history of the Avalon is not well understood. The area is generally described as "heavily glaciated" although the evidence for glaciation consists more of erosional landforms and depositional landforms composed of thin drift units. No extensive areas of thick glacial sediments are reported in the literature.

No substantial evidence has been reported for glaciation prior to the last (late Wisconsin) glaciation.

During the last glaciation ice may have been thin (probably less than 700 m) forming a dome over the head of St. Mary's Bay. Striations, streamlined bedrock and Rogen

moraine indicate that ice divides were established up the centre of the Bay de Verde and St. John's Peninsulas, delivering ice down the slope of land to the coast (Henderson, 1972). The Avalon ice sheet may therefore have been thinnest on its northern flank and thus more directed by subglacial bedrock relief (Batterson, 1983). The margin of the ice sheet was probably close to the present coastline (Rogerson, 1974). Grant (1977) suggested that areas on the tips of several peninsulas may have escaped late Wisconsin glaciation and cited the extensive felsenmeere (block fields) which occur on the plateau of the southern Avalon as evidence of no glacial erosion there. Eyles and Slatt (1977) reinterpreted these as evidence of a cold-based, non-erosive ice margin and cited the stacked tills at St. Vincents as further evidence of cold-based ice melt-out as described in Svalbard (Boulton, 1972). The cold-based hypothesis is possible but unlikely and a recent field trip to the area with Eyles concluded that one might reinterpret the stacked tills at St. Vincents as fluvioglacial outwash sediments on lodgement.

Good evidence exists to indicate that deglaciation was late and proceded with the down-wasting of the ice sheet. Macpherson (1981 and subsequently) has recovered dates which show a direct relationship between age of pond-bottom organics and height above sea level. The oldest date, just

over 10,000 years old was obtained from a pond in the Hawke Hills while dates in the order of 8,000 years old were obtained from nearby lower ponds. Glacial drainage channels on the flanks of the Hawks Hills appear to confirm their early emergence above the down-wasting ice sheet.

Deglaciation was accompanied by coastal submergence which has drowned early Holocene beaches or glacial deltas and which probably continues at a rate of 5 mm/year (based on the Port aux Basques tide gauge, (Don Forbes, personal communication, 1984). Good morphological evidence of contemporary submergence can be obtained from Pointe La Haye where a peat bog is being actively eroded, its base below present high tide level, and at Mutton Bay, Trepassey where the inland migration of a barrier beach has moved from the seawards to the landwards side of a rock knob in the last 50 years (Don Forbes, personal communication, 1984).

2.1.5 Unconsolidated sediments

The Avalon is generally covered by a thin (<5 m) discontinuous drift of variable textures and often of uncertain origin. The sedimentary characteristics of subglacial and supraglacial melt-out tills were first described by Slatt (1972) in the Butterpot area. Tills there are very poorly sorted with a mean grain size in the medium

sand range, but essentially non-modal. These characteristics are independant of rock type, and ascribed by Slatt to short distance of glacial transportation.

Tills described by Henderson (1972) indicate lodgement with variable amounts of silt-clay (maximum 43 percent, minimum 8 percent) generally in the order of 25 percent. He comments that the major effect of great variations in till thickness is to reduce the relative relief by filling in small bedrock hollows. He describes maximum thicknesses in the order of three to six metres on the plateau surfaces of the peninsula with far greater depths occuring in the central Avalon lowlands and along several sections of the Cape Shore and Southern Shore.

A detailed examination of drift in the Waterford valley (Batterson, 1983) which included a map of thickness of overburden (less than 5 percent of the area with drift >4 m), confirms the local nature of the tills. Three till units are described, rarely occuring at a single sample site. They consist of an overconsolidated, slightly fissile, very poorly sorted lodgement which is bimodal in grain size and is the most extensive basal unit: a poorly-sorted clast supported gravel which may be a supraglacial melt-out till and a compact poorly-sorted bimodal to polymodal drift with striated clasts with silt-clay coatings typical of subglacial

melt-out till. Batterson estimated transportation distances of less than 2 km as indicated by clast lithologies.

Virtually all of the tills described by Slatt (1972) and Batterson (1983) have less than 20 percent silt-clay and are predominantly rich in clasts.

The central part of the Avalon Peninsula, approximately between the Salmonier line and Whitbourne contains perhaps the most interesting glaciogenic sediments and depositional landforms. The area was described as one of end moraine on the map accompanying Henderson's Memoir (GSC Map 1320A). The region has been reinterpreted as Rogen moraine (formerly called ribbed moraine) which is a subglacial deposit where till ridges are oriented normal to glacial flow direction (Rogerson and Tucker, 1972). Till fabrics taken from the ridges in the Ocean Pond area appeared to support their subglacial origin.

Sediment textures are probably very variable. Most of the significant fabrics were obtained from lodgement, where clasts were matrix-supported and silt-clay probably exceeded 20 percent by weight. However, many sites of clast-supported boulder-rich deposits were observed in railway cuts and other artificial sections. These may represent melt-out units or even fluvioglacial materials draped over the Rogen moraine

during down-melting of the overlying ice.

Relief on the Rogen moraines indicates very variable drift thicknesses, but certainly up to 30 m. Ponds which characteristically drown the swales between the ridges are noticeably shallow and often floored with very large boulders.

Recent reinterpretation of certain Rogen moraines in Western Europe suggests they may be recessional moraines and mark the shrinking boundary of an ice sheet. This is possible but has not been tested for the Rogen moraines of the Avalon.

Some of the thickest drift deposits occur in restricted units at the heads of bays such as Witless Bay, Bay Bulls, Middle Cove, Ferryland, in the Seal Cove area and at the mouth of Holyrood Pond and Peters River. Drift in the latter two locations forms cliffs up to 25 m high which were interpreted as lodgement overlain by outwash and delta sediments (Rogerson and Tucker, 1972). The basal lodgement is a compact (vertical standing cliff) of matrix-supported clasts with over 30 percent silt-clay, while the stratified drift overlying it is well-sorted loose medium sand with generally less than 10 percent silt-clay.

Samples taken from the drift section west of St.

Vincents, which has over 35 m of drift on a steep bedrock slope outcropping just above sea level, were interpreted by Eyles and Slatt (1977) as lodgement, melt-out and flow till units consistant with deposition from cold-based ice. The tills were described as non-modal silty sands with over 30 percent silt-clay. No clear differentiation of flow and melt-out units occurs in the section which may be better interpreted as consisting of two or three lodgement sheets surmounted by outwash.

Sections at St. Shott's contain some very clay rich diamicts (>20 percent clay) which may be more typical of flow tills, while samples taken from the 8 m cliff at Middle Cove, in complex stratified drift, varied between 33 percent clay and only 3 percent clay.

The 30 m thick section at St. Shott's is described by Henderson (1972) as stratified sandy drift between two sheets of till, the former being interpreted as outwash. Henderson describes the thickest drift section on the Avalon (over 70 m) from the Cape Shore in the vicinity of Great Barasway. It also consists of a basal till-like diamict, overlain by stratified drift and capped with another till. It is uncertain whether these sections are of tills and outwash or complex melt-out and flow tills.

Outwash is most extensive in the broad sandur between Topsail and Seal Cove which overlies Cambro-Ordovician lowlands. At Seal Cove the outwash consists of large to medium boulders, moderately rounded, in clastic contact with a fine gravel to sand matrix. Many of the boulders are granitic and derived from the Holyrood batholith to the south. Cambro-Ordovician clasts are usually friable and small, but may be relatively important in providing matrix sediments. At Seal Cove the outwash is over 15 m thick.

Stratified drift, in the form of well sorted sand and gravel with less than 5 percent silt-clay is associated with several esker deposits on the Southern Avalon Peninsula. The longest, over 8 km long, runs towards Chance Cove while others such as north of Cappahayden, in the Old Sams drainage basin and between St. Bride's and Branch are in the region of 5 km long. The most extensive esker/kame-terrrace deposits occur in the latter area, especially at Cuslett Brook and along the Southeast River which lies close to the Placentia to Colinet Road. Many of these eskers are surmounted by boulders which probably represent supraglacial melt-out during final ice melt.

Other surficial materials on tne Avalon consist of rather limited fluvial sands and gravels and beach sediments which vary from sand (rare) to cobble (common) to large

boulders.

Due to the circumstance of rising sea level, fluvial sand/gravels are limited, occuring most notably in valleys of Southern Avalon: Peter's River, Crossing Place River, Salmonier River, Branch River and Lance Brook being the most extensive. They provide good land for grazing and garden produce.

The most extensive beach deposits occur at Argentia and Placentia in the form of cuspate spits with multiple accretionary ridges. Barachois type beaches or barrier beaches are most common around the Southern Avalon where their survival is probably related to available sediments from tills and outwash. They occur at O'Donnel's, Shoal Bay, Mall Bay, Point La Haye, St. Vincents, Trepassey, Biscay Bay, Portugal Cove South; Freshwater Bay near St. John's and fronting the area of outwash between Topsail and Seal Cove. Most are composed of coarse gravel and boulders. At Portugal Cove South the crest of the beach is approximately 10 m above sea level, at St. Vincents over 8 m.

2.2 Bedrock Geology

2.2.1 Introduction

The Appalachian Orogen in Newfoundland has been divided into four main tectono-stratigraphic zones (Fig. 2.1, index map), each displaying a distinctive pre-Silurian evolutionary history (Williams, 1976,1978; Williams and Hatcher, 1983). The Humber and Dunnage Zones of western and central Newfoundland record the development of the ancient continental margin of North America and the subsequent destruction of the Paleozoic Iapetus Ocean (Proto-Atlantic) with its oceanic crust and island arc successions (e.g. Stevens, 1970; Strong and Williams, 1972; Malpas et al ., 1973; Williams and Stevens, 1974). Although the Paleozoic Gander Zone includes elements of the Iapetus, the more enigmatic Avalon Zone to the east has been interpreted as an ancient fragment of northwest Africa incorporated into the Appalachian Orogen during Paleozoic times (O'Brien et al.,1983; King and O'Brien, in press). The Precambrian evolution of the Avalon Zone predates Iapetus and marks the original westward extension of the Pan-African Orogeny (circa 900-570 Ma) of Morocco (King and O'Brien, in press).

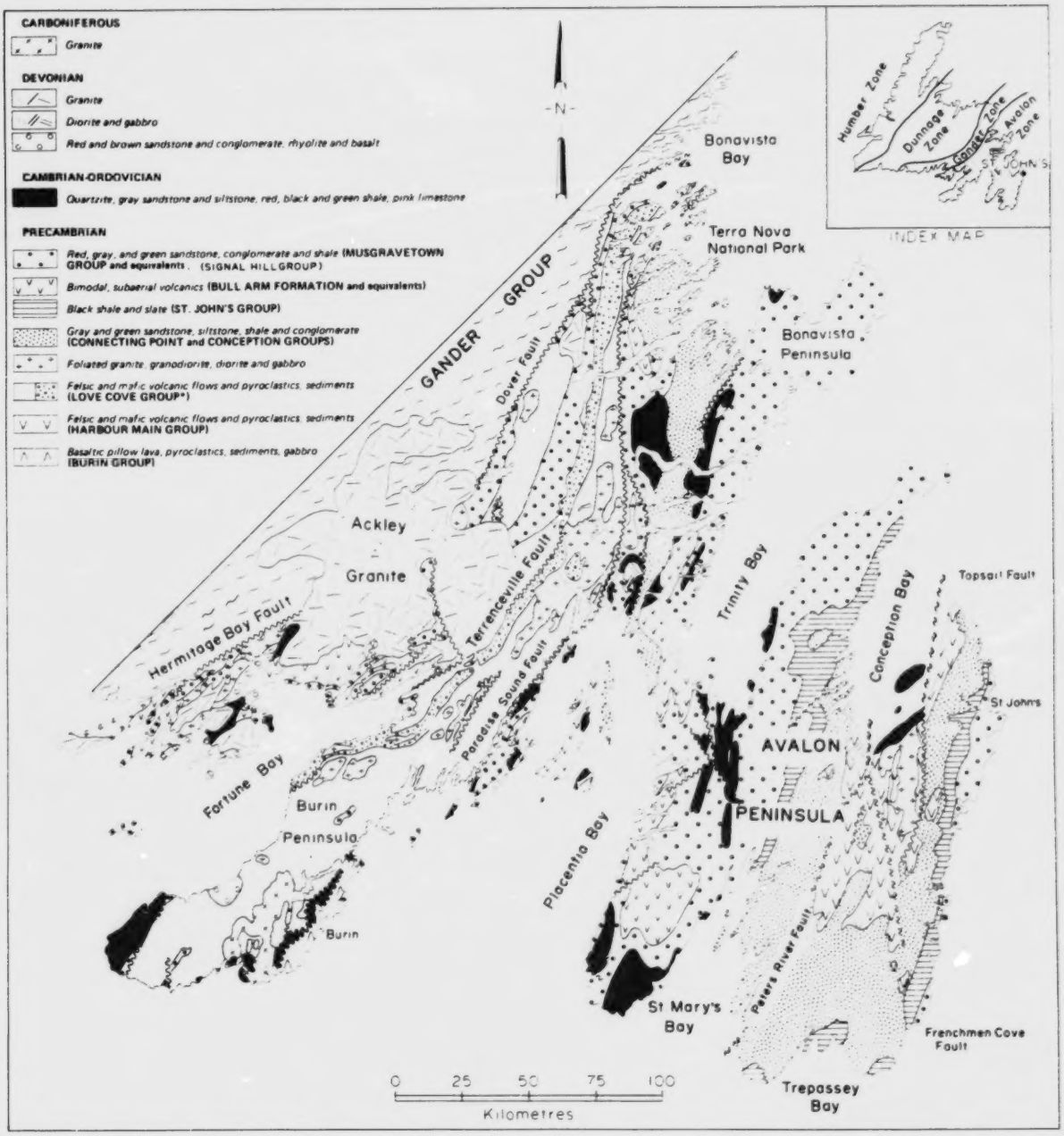


Figure 2.1 Geological map of the Avalon Zone of Newfoundland. The index map shows the principal tectonostratigraphic zones of the Newfoundland Appalachians (after King and O'Brien, in press).

The Avalon Zone is in tectonic contact with the remainder of the Appalachians along the entire length of the orogen. In Newfoundland, the western margin of the Avalon Zone is the Dover-Hermitage Fault (Blackwood and Kennedy, 1975; Blackwood and O'Driscoll, 1976). No clear genetic links across this fault are evident until the Devonian, when sediments deposited in the Avalon Zone contain detritus from the westerly adjacent Gander Zone. Final juxtaposition of the Gander and Avalon Zones (as shown in Figure 2.1) was completed prior to the intrusion of the 355 Ma, post-tectonic Ackley Granite (Dallmeyer et al., 1981, 1983).

The Avalon Zone in Newfoundland is a terrane consisting of Late Riphean (1000-670 Ma) to Vendian (670-590 Ma) bimodal volcanic rocks, associated turbidite and molasse-like sedimentary rocks, and granitoids, overlain by Paleozoic shallow marine and terrestrial sediments and minor volcanic rocks. The Zone continues in the offshore Grand Banks of Newfoundland for some 250 km to the present continental margin (Lilly, 1966; Pelletier, 1971; Miller, 1977; Haworth and Lefort, 1979). Correlatives occur in Nova Scotia (Keppie and Schenk, 1982), New Brunswick (Ruitenberg, et al., 1973), Massachusetts and the Carolinas (Rast, 1980; Skehan and Murray, 1980; Hatcher et al., 1980). Similar rocks occur in the southern part of the British Caledonides, the Hercynides of France and Iberia and in the northern and eastern margins

of the west African shield (e.g. Rast et al., 1976; Rast, 1980; O'Brien et al., 1983).

This part of the report summarizes the late Precambrian and early Paleozoic lithofacies, faunal assemblages and tectonic elements of the Avalon Zone of the Avalon Peninsula, Newfoundland.

2.2.2 General Geological Setting

The Avalon Zone of Newfoundland includes three distinct geological regions bounded by major faults: (1) northern Fortune Bay region, defined by the Hermitage Bay and Terrenceville Faults; (2) most of the Burin Peninsula, bounded by the Terrenceville and Paradise Sound Faults; (3) the Bonavista-Terra Nova region and the Avalon Peninsula, to the east of the Paradise Sound Fault (Fig. 2.1). Lithological correlations indicate some degree of formational homogeneity in the 10 km thick sequences of Precambrian rocks.

In the Avalon Peninsula (Fig. 2.2), major Riphean to mid-Paleozoic facies and formations include, in ascending order:

1a. Latest Riphean to Vendian marine and subaerial bimodal volcanic rocks - the Harbour Main Group and the Bull Arm Formation (Musgravetown Group).

1b. Associated marine volcaniclastics and turbidites - the Conception and Connecting Point Groups;

2a. A Vendian shallowing upwards sequence of marine shale, silt, and sand - the St. John's Group.

2b. A coeval alluvial plain clastic and subaerial volcanic sequence - the Signal Hill and Musgravetown Groups;

3. A Basal Cambrian (Tommotian) shallow marine orthoquartzites and siltstones - the Random Formation.

4. Lower Cambrian variegated shale, pink sabka-type limestone and red shale - the Bonavista, Smith Point and Brigus Formations respectively;

5. Middle Cambrian, Paradoxides -bearing grey to black shale pillow-basalt and tuff - Chamberlain's Brook and Manuels River Formations;

6. Upper Cambrian grey and green shale - Elliot Cove Formation;

7. A Tremadocian shallowing upwards sequence of marine shale, siltstone, sandstone, quartzite and oolitic ironstone - the Clarenville and Bell Island Groups;

8. An Arenigian intertidal and shallow marine sequence of sandstone, quartzite, oolitic ironstone and shale - the Wabana Group;

9. An associated suite of gabbro, diorite and granitoids.

Silurian marine shales have been obtained from submarine drill cores and dredge samples on the Grand Banks east of St. John's. Devonian-Carboniferous sedimentary and volcanic rocks

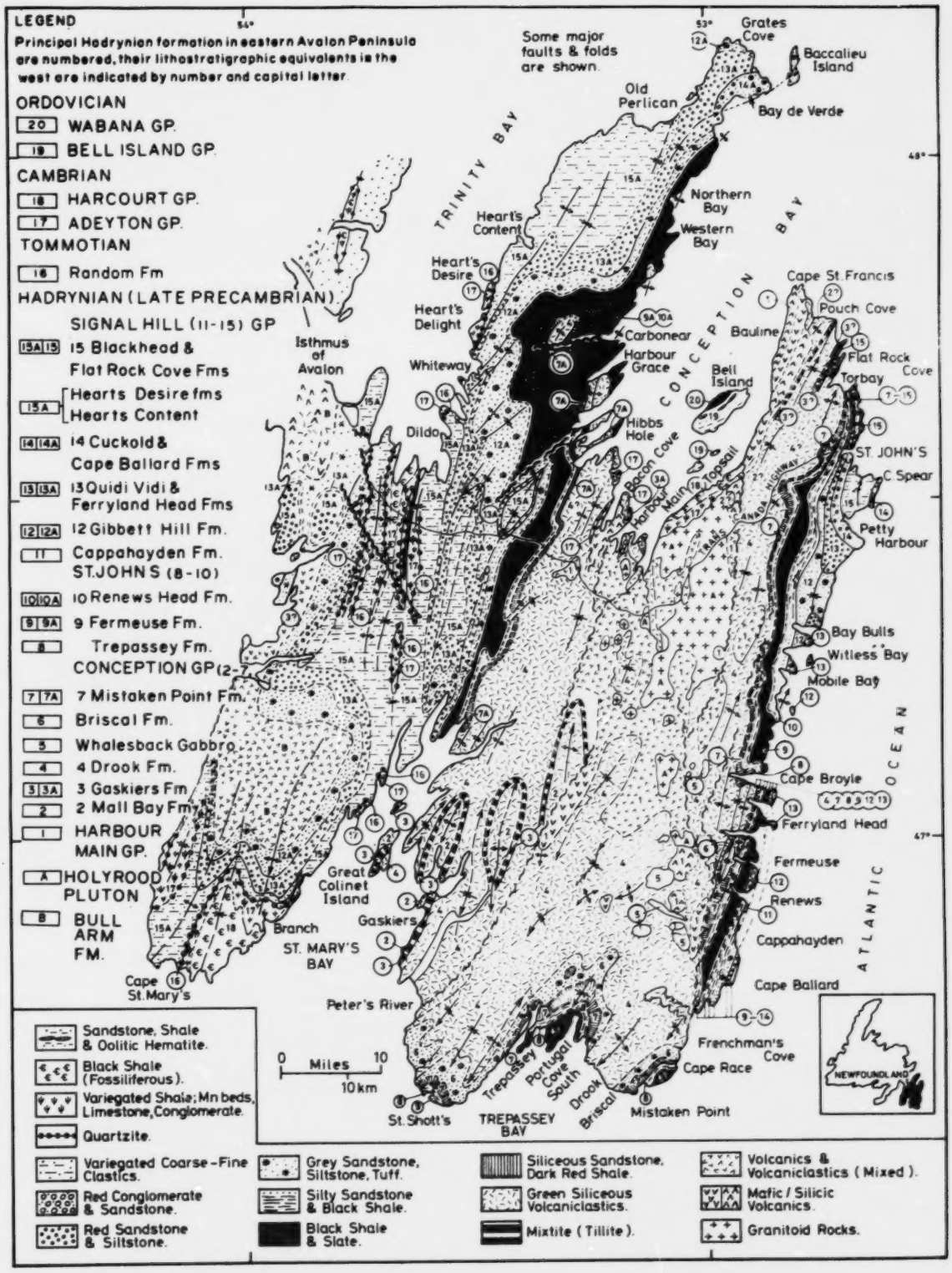


Figure 2.2 Geological Map of the Avalon Peninsula (after King and O'Brien, in press).

have only been found in the Burin Peninsula-Fortune Bay area, where they unconformably overlie the Cambro-Ordovician and Precambrian successions.

Three periods of deformation have been identified in the Avalon Zone of Newfoundland: (1) an enigmatic Late Riphean to Vendian (Cadomian or Pan-African) Orogenic episode, named the "Avalonian" by Rodgers and first described as the "Avalon Orogeny" by Lilly (Hughes, 1970, 1972); (2) a major Siluro-Devonian (circa 395 Ma) disturbance - the "Acadian Orogeny"; and (3) a poorly defined Late Carboniferous (Hercynian) deformation represented by granitoid plutonism and possibly by localized folding and faulting.

Bedrock geology largely controls the physiography of the region.The youngest Precambrian rocks occur in major folds and roughly follow the present coastline (eg. Figs. 2.3, 2.4, 2.5) with the oldest volcanic and sedimentary rocks forming the core of the peninsula (Fig. 2.2).

2.2.3 Avalon Zone Facies Analysis and Facies Models

Late Riphean to Vendian Subaerial and Marine Volcanism

Mafic and felsic volcanic rocks which formed mainly in a subaerial environment between circa 750 and 570 Ma, are

diagnostic of the Avalon Zone throughout the entire eastern margin of the Appalachians.

The Harbour Main Group (Rose, 1952) underlies much of the central Avalon Peninsula (Figs. 2.1 and 2.2) and is disposed in three lithologically distinct fault blocks (Rose, 1952; McCartney, 1967; Papezik, 1969, 1970; Hughes and Bruckner, 1971; Williams and King, 1979). An eastern block to the east of the Topsail and Frenchman's Cove Faults, is dominated by pillow lava and aquagene tuffs intruded by rhyolitic domes dated at 585 Ma U/Pb/Zircon (Krogh et al., 1983). The central block, to the south of Conception Bay includes felsic and mafic flows, pyroclastics and minor volcaniclastics, intruded by 620 Ma (Krogh et al., 1983) high level granite of the Holyrood plutonic suite; these rocks are unconformably overlain by fossiliferous Lower Cambrian shale and limestone. The western block, exposed in the Avondale-Harbour Main area of southwestern Conception Bay, is characterized by well-preserved acidic ash-flow tuffs locally intercalated with fluvial and lacustrine volcanogenic sediments and overlain by terrestrial massive and amygdaloidal basalt flows. On the basis of their chemistry and mineralogy the basic flows are classified as hawaiites and mugearites, metamorphosed under conditions of the prehnite-pumpellyite facies (Nixon and Papezik, 1979).

The Harbour Main Group in general is characteristically mildly alkalic to tholeiitic (Papezik, 1970; Nixon and Papezik, 1979). Much of the eastern block was formed in a shallow marine environment, in contrast to the typical subaerial depositional environments to the west.

The Bull Arm Formation (McCartney, 1967), a volcanic sequence within the lower part of the continental clastic Musgravetown Group (Hayes, 1948), is well exposed on the isthmus of the Avalon Peninsula and between Long Harbour and southeast Placentia (Fig. 2.1). It is poorly exposed in the major dome between Placentia and St. Mary's Bays (Fig. 2.2). The formation is a bimodal suite of basalt, rhyolite, and associated volcaniclastics with a variable aggregate thickness of about 2.5 km (McCartney, 1967; Hughes and Malpas, 1971).Conspicuously red rhyolitic lavas of the Bull Arm Formation exposed in the Doe Hills on the Isthmus of Avalon, contain up to 10 percent K_2O; associated pale green volcanic rocks, rich in zoisite, contain up to 12 percent CaO. Barite occurs on joint surfaces and in veins up to 30 cm thick. The red lavas contain "phenocrysts" of turbid, untwinned orthoclase formed by replacement of original plagioclase, similar to rocks at Yellowstone National Park where groundwaters are actively replacing plagioclase by orthoclase at 200°C (Hughes and Malpas, 1971). Hughes and Malpas describe the Bull Arm Formation as a

spilite-keratophyre succession affected by intense sodium metasomatism, which masked the original chemical characteristics.

The Bull Arm Formation on the Isthmus of Avalon Peninsula is underlain by turbidite-facies sandstone and shale of the Connecting Point Group. King (1980) suggested that Bull Arm volcanism was an important source of ash for the tuffaceous Gibbett Hill Formation to the east and thus may be significantly younger than and unrelated to the Harbour Main Group volcanism. The metasomatism of these rocks probably accounts for an anomalous Rb/Sr isochron age of 467 Ma.

Vendian Marine Sedimentation

Marine volcaniclastic sediments are well exposed on the Avalon Peninsula and are termed the Conception Group (Rose, 1952). Comparable facies on the isthmus and to the west are known as the Connecting Point Group (Hayes, 1948).

The Conception Group is a 2 to 5 km thick sequence representing widespread marine turbiditic and pelagic sedimentation that is in part contemporaneous with and in part later than the volcanism of the Harbour Main Group. Williams and King (1979) divided the group present in

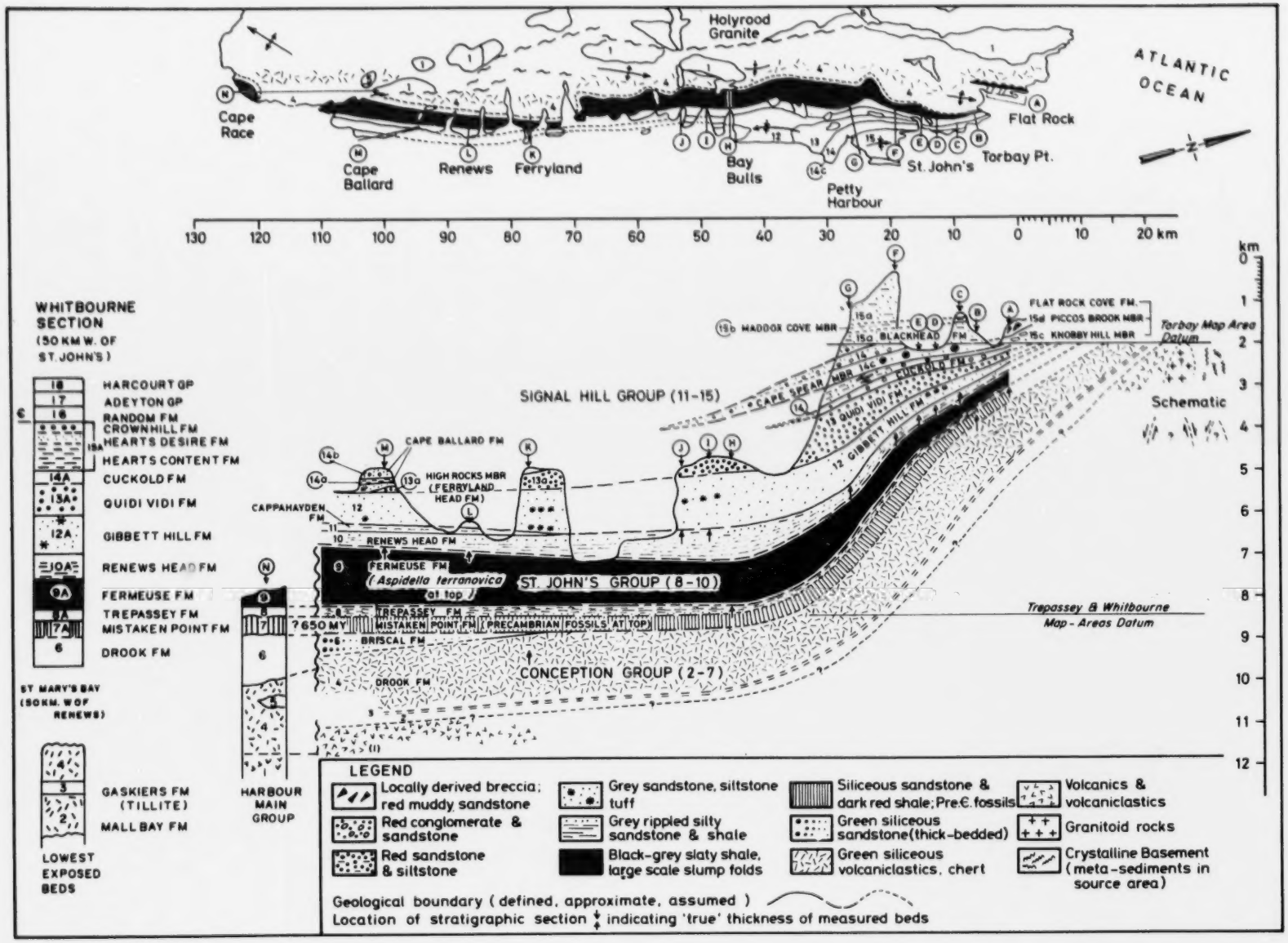


Figure 2.3 Stratigraphic section of Eastern Avalon Peninsula (after King and O'Brien, in press).

southern Avalon Peninsula into five sedimentary formations. King (1980) mapped these formations elsewhere on the Avalon Peninsula (Figs. 2.2 and 2.3) and suggested they may be important in global stratigraphic correlations. A distinctive tillite unit up to 300 m thick in eastern St. Mary's Bay (Gaskiers Formation) occurs near the base of the group; it is provisionally correlated with till-like beds in the Bacon Cove area of southwestern Conception Bay (Fig. 2.2), and Red Head (Fig. 2.6). Green siliceous silty sandstone and bedded cryptocrystalline chert of volcanic origin (Drook Formation) form the bulk of the Conception Group, and are well exposed south of the Avalon wilderness area and in the eastern part of the Avalon Peninsula, especially in a narrow belt between Portugal Cove South and Torbay (Fig. 2.2). Precambrian metazoan fossils are well preserved in a number of stratigraphic levels above the chert, especially in the distinctive green and red tuffaceous silty sandstone unit (Mistaken Point Formation), chosen by Williams and King (1979) to define the top of the Conception Group. The Hibbs Hole Formation (Hutchinson, 1953) has been traced from its type locality in southwestern Conception Bay southeast to St. Mary's Bay, and is a correlative of the Mistaken Point Formation. The tillite and metazoan fossils are discussed by Anderson and King (1981) and Anderson and Morris (1982). It is uncertain if the Gaskiers Formation was a consequence of the Varangian glaciation although it was probably deposited

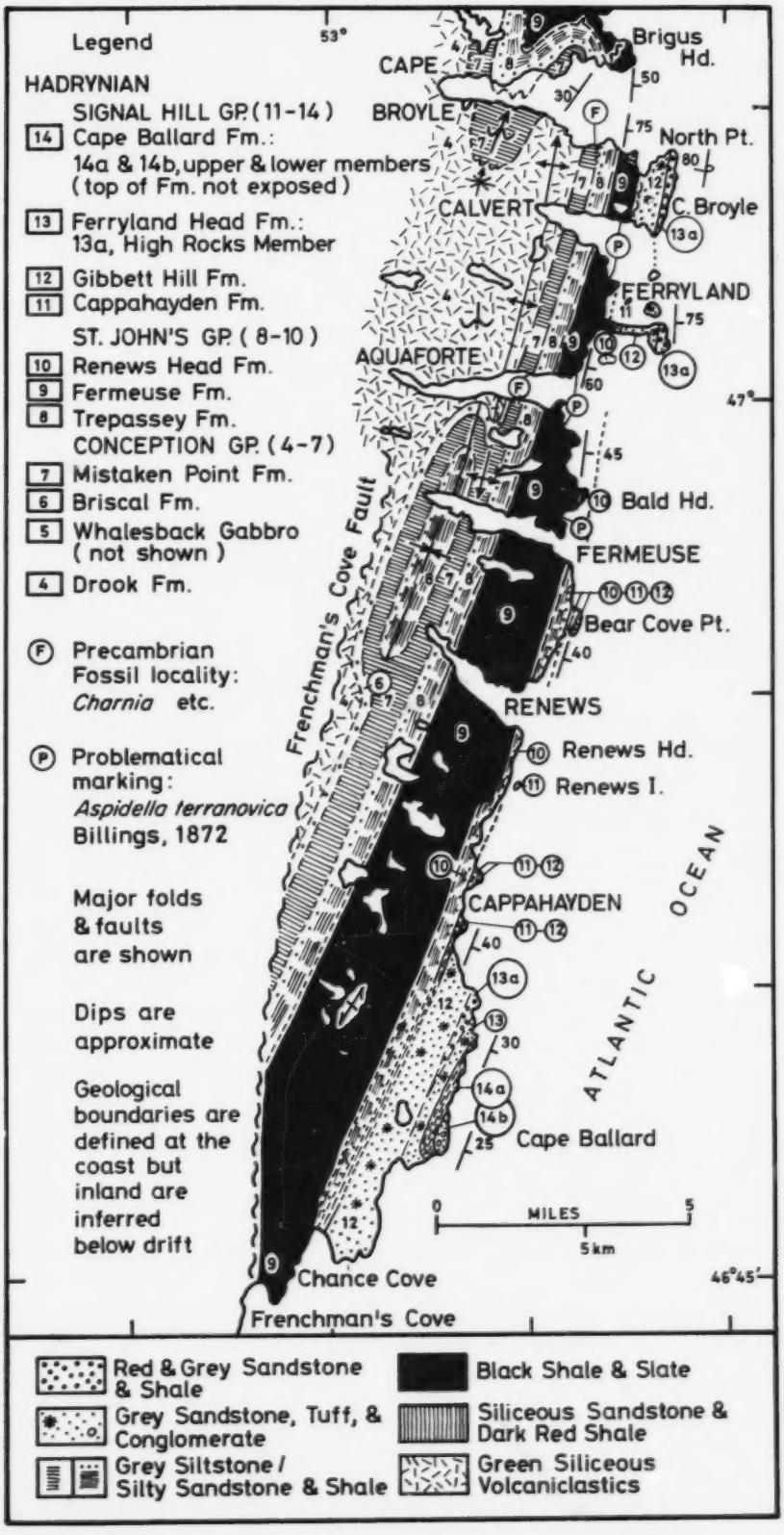


Figure 2.4 Geological map of the Cappahayden-Ferryland area (after King, 1982).

sometime between 730-660 Ma.

The Connecting Point Group is a fault-bounded stratigraphic unit, the base of which is not exposed; the total thickness of the Group was estimated by Jenness (1963) to be 7.5 km. In western Placentia Bay, the Connecting Point Group has been subdivided by O'Driscoll and Muggridge (1979) into a lower turbidite unit of graded sandstone and siltstone, an overlying deltaic unit of shale and sandstone, and an upper molasse-like unit consisting of green pebbly sandstone and coarse conglomerate. Comparable units have been recognized on the Isthmus of Avalon by King (1982) who has tentatively correlated the lower turbidite unit with the upper part of the Conception Group and the deltaic unit with the St. John's Group. The deltaic unit of the Connecting Point Group is the most prolific Late Riphean to Vendian micro-fossil level in the Avalon Zone of Newfoundland (Hofmann et al, 1979).

The Conception Group is conformably overlain by up to 2 km of marine shale and interbedded sandstone of the St. John's Group (Williams and King, 1979), a deltaic sequence (King, 1980) which progrades and thickens southward (Figs. 2.3 and 2.4). Greenish grey tuffaceous siltstone and thin sandstone form the lowermost unit (Trepassey Formation) and represent a transitional zone into the underlying Mistaken

Point Formation with its distinctive metazoan fauna. Grey to black shale, minor buff sandstone and slumped-beds of sandstone, comprise the middle unit (Fermeuse Formation, Williams and King, 1979). The shales contain some Vendian microfossils, (Hofmann et al., 1979). Problematical markings Aspidella terranovica, Billings, 1872, occur at the top of the Formation and are well exposed at Ferryland (Fig. 2.4). The upper unit (Renews Head Formation, Williams and King, 1979) consists of thin, lenticular-bedded rusty-brown weathering sandstone with thin, dark shale laminae; it represents a shoaling of the marine basin. The lower division of the Carbonear Formation (Hutchinson, 1953) of western Conception Bay has been correlated with the Fermeuse Formation and the upper division with the Renews Head Formation (King, 1980).

Vendian Fluvial Sedimentation

Alluvial plain conditions developed across the Avalon Zone by latest Vendian time in response to major uplift (north of the present Bonavista and Avalon Peninsulas) related to the Avalonian Orogeny. This period is represented by clastic rocks of the Signal Hill Group (Williams and King, 1979) on the Avalon Peninsula and by the volcanic and clastic successions that comprise the Musgravetown Group and equivalents to the west. The clastic successions of both

groups contain grey and green tuffaceous siltstone and arkose at the base, which are overlain by red and green arkose and conglomerate.

The Signal Hill and Musgravetown Groups represent the transition from marine to alluvial plain sedimentation. The grey sandstones (Gibbett Hill Formation) and correlatives (Big Head and Halls Town Formations) are interpreted as delta plain deposits, which in turn are overlain by red sandstones (Quidi Vidi Formation) and correlatives (Maturins Pond and Whiteway Formations) interpreted as alluvial plain deposits. Facies developed in the overlying conglomerate (Cuckold Formation) and correlatives (Bay de Verde conglomerate), are characteristic of braided-river deposits. Pebbles in the conglomerate are mainly volcanic. They decrease in size southward (Fig. 2.5) and pass into a red sandy facies that resembles the overlying red beds (Blackhead Formation) near St. John's; it is therefore desirable to use a new name for these combined units where indistinguishable farther south, i.e. Ferryland Head Formation (Fig. 2.4). Paleocurrent studies indicate mainly southward flowing streams (Fig. 2.5). The decrease in pebble size, the relatively high silt content, and the presence of thixotropic deformation structures indicate a more distal alluvial-plain environment to the south. Rock fragments and constituent detrital minerals indicate that the Signal Hill Group and correlatives were derived largely from a source area of Harbour Main,

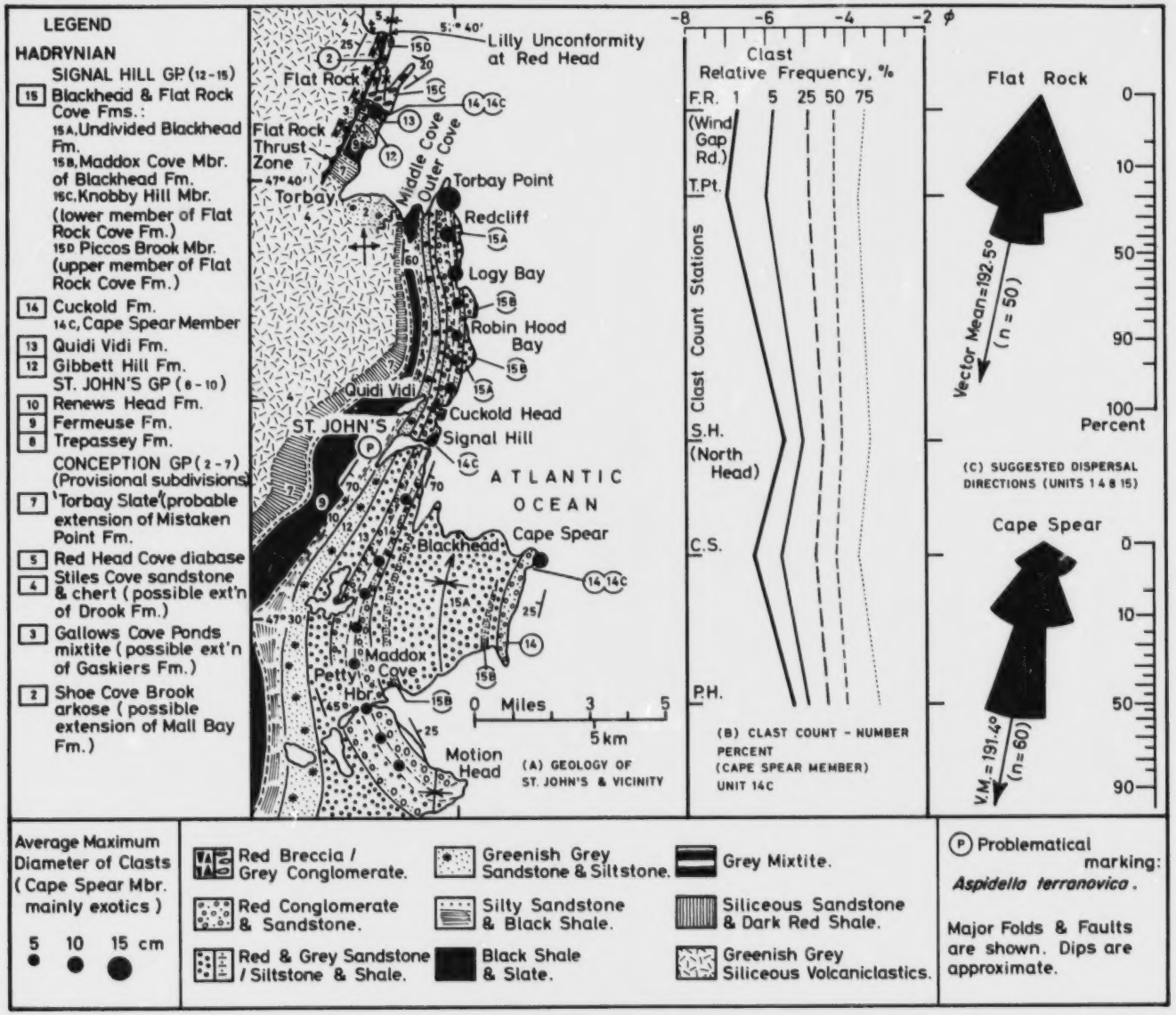


Figure 2.5 Geology of St. John's and vicinity (after King, 1982).

Conception, and Holyrood rocks. However, the Gibbett Hill Formation also contains small amounts of detrital garnet and muscovite (Papezik, 1973); this, together with a northerly to northeasterly provenance of the Signal Hill Group sediments (King, 1977, 1980), may indicate the presence of basement rocks on the continential shelf to the northeast of the Avalon. The presence of tuff and ash beds in the St. John's and Signal Hill Groups indicates contemporaneous, sporadic, volcanic activity somewhere in the region. Marine shale and sandstone (Unit 15A of Figs. 2.2 and 2.3) overlie the Whiteway Formation of western Avalon Peninsula but have no precise correlation with the Blackhead Formation. The marine sediments are overlain by alluvial plain conglomerate of the Crown Hill Formation, the highest unit of the Musgravetown Group in the Trinity Bay area.

Cambro-Ordovician Sedimentation and Volcanism

A now dispersed cover sequence of platformal Cambro-Ordovician sedimentary and volcanic rocks overlies the upper Proterozoic volcanic, sedimentary, and granitoid rocks (Fig. 2.2). The basal Cambrian contact may be represented as an unconformity, nonconformity or disconformity.

The Random Formation (Walcott, 1900) is a transgressive and regressive sequence of basal quartz-pebble conglomerate,

orthoquartzite, sandstone, siltstone and shale that is exposed on the Avalon, Bonavista and eastern Burin Peninsulas (e.g. Butler & Greene, 1976). It represents an eastward transgressive shallow marine beach or barrier sand above the Crown Hill Formation and marks the beginning of the Cambrian depositional regime (McCartney, 1967). The distinctive white and reddish orthoquartzite of the Random Formation in the Villa-Marie area is remarkably pure; it is quarried and used as a flux in the manufacture of elemental phosphorus at Long Harbour, Placentia Bay, 20 km to the southwest.

According to Anderson (1981), the Random Formation probably correlates with all but the uppermost part of the middle or Dokidocyathus regularis Zone of the Tommotian Stage, the basal stage of the Cambrian succession of the Siberian platform in the USSR. The base of the Random in western Avalon Peninsula is diachronous but not markedly so, because the diachronism falls well within the time-span of the Tommotian. The upper member of the Cape Ballard Formation (Williams and King, 1979) of eastern Avalon Peninsula (Fig. 2.4) is a possible correlative of the Random Formation (King, 1980).

The Random Formation is disconformably overlain by platformal sediments of the Adeyton Group (Jenness, 1963) which includes the Bonavista, Smith Point, Brigus and

Chamberlain's Brook Formations. The lower part of this group includes a Lower Cambrian succession of Coleoloides - bearing red and green shale and stromatolitic limestone (Bonavista Formation, Van Ingen, 1914), pink algal limestone (Smith Point Formation, Walcott, 1900) and Callavia - bearing red and green shale and limestone (Brigus Formation, Hutchinson, 1962).

The overlying Middle Cambrian succession of P. bennetti bearing shale (Chamberlain's Brook Formation, Howell, 1925) and the P. davidus - P. hicksi bearing black shale (Manuels River Formation, Hutchinson, 1962) are locally intercalated with minor pillow basalt and tuff. A manganese carbonate-oxide bed, yielding 25 percent manganese and 4 percent phosphorus in the Topsail area (Rose, 1952), defines the base of the Middle Cambrian; it marks an important non-sequence or virtual cessation of deposition in the Conception Bay area as the upper part of the Brigus Formation and the lower part of the Chamberlain's Brook Formation are missing. The missing beds are present in the Cambrian succession on the Cape St. Mary's Peninsula (Fletcher, 1972; Bengston and Fletcher, 1983). The Manuels River and overlying Elliot Cove and Clarenville Formations comprise the Harcourt Group (Jenness, 1963).

Upper Cambrian dark grey and green micaceous shale and

minor sandstone (Elliot Cove Formation, Van Ingen, 1914) include the Agnostus, Olenus and Peltura trilobite zones (Hutchinson, 1962; McCartney, 1967). The appearance of sand layers and the abundance of detrital mica in the shale indicate increasing supply of clastic debris, hence increasing erosion in the source area.

The northwestward-dipping Cambrian succession at Manuels extends under Conception Bay and is overlain by an estimated 900 m of Lower Ordovician (Tremadocian) shale, siltstone and sandstone, which are presumed equivalents of the Clarenville Formation (Van Ingen, 1914). An estimated 1400 m of reddish-brown to grey micaceous sandstone, siltstone, and oolitic ironstone beds of the Tremadocian-Arenigian Bell Island Group (Rose, 1952) lie above, and are exposed on Kelly's, Little Bell, and Bell Islands (Fig. 2.2); the exposed thickness of the group on Bell Island is 600 m.

Most of the Bell Island Group is interpreted as having formed in an intertidal-supratidal environment. Pinching and swelling of sandstone beds above black organic-rich shale was probably due to tidal channels changing their course. Lenticular-bedded, fine-grained, grey micaceous sandstones display eolian ripples, interference ripples and mud-cracked bedding surfaces. An account of the trace fossils is given in Hayes (1915), Seilacher and Crimes (1969), Bergstrom (1976)

and Pickerill and Fillion (1983). Acritarchs and trilobites from Bell Island are described by Dean and Martin (1978).

A prominent northeast trending ridge of thick bedded white quartzose sandstone forms the backbone of Bell Island. This 90 m thick unit (the Redmond Formation, Van Ingen, 1914) shows a variety of structures including megaripples, herringbone cross-stratification, and primary current lineations; it is interpreted as a migrating offshore sand bar. Dean and Martin (1978) placed the Tremadocian-Arenigian boundary below the orthoquartzite or about 400-500 m below the base of the Wabana Group. A 3 to 11 m thick unit of oolitic ironstone (the Dominion Formation, Van Ingen, 1914) marks the top of the Bell Island Group.

An erosional disconformity above the ironstone defines the base of the Arenigian Wabana Group (Van Ingen, 1914). About 100 m of graptolitic black shale and sandstone, oolitic ironstone, oolitic pyrite, and phosphatic pebble beds crop out on the west side of Bell Island and dip 8^{o} northwestward under the bay. Submarine exploration carried out during mining of the ironstone suggests that the Wabana Group is at least 355 m thick and that the Lower Ordovician succession occupies a fault-bounded, north-northeast trending basin centered 3 km north of Bell Island. The oolitic ironstone shows interference ripple marks, cut and fill structures, and

rain-drop impressions and contain brachiopods, trilobites and micro-planktonic fossils.

Vendian and Paleozoic Magmatism

Granitoid plutons are an important component of the eastern margin of the Appalachians. In the Avalon Zone of Newfoundland, two major episodes of plutonism are recognized (O'Brien et al., 1983). The first, yielding isotopic ages mainly between 570 to 620 Ma, are hornblende-biotite adamellites and granites of the Avalon Peninsula which were intruded during the closing stages of late Precambrian orogenesis. These granitoids are locally calc-alkaline. The second plutonic episode, dated about 360 Ma, produced granites locally of batholithic proportions which were introduced during late stages of Acadian orogenesis (Strong,et al., 1978b). These granites were intruded into high crustal levels in the western Avalon Zone of Newfoundland and are locally mineralized (e.g. fluorite-bearing St. Lawrence Granite).

The Holyrood Granite (Buddington, 1919) dated at 620 Ma (Krogh et al., 1983) consists mainly of granite and granodiorite, with minor amounts of quartz monzonite and gabbro. Aplite dykes and small bodies of pegmatite and granophyre are present near the margins and are believed by

Hughes (1971) to indicate high-level intrusion. The granite is typically medium to coarse-grained and composed of about 30 to 40 percent quartz, 30 to 35 percent microperthite and 15 to 20 percent oligoclase (feldspars are commonly altered to sericite and/or clay minerals); chloritized biotite, and minor amounts of sphene, zircon, apatite and epidote complete the mineral assemblage (McCartney, 1967; Hughes, 1971). The pluton is discordant, with numerous angular inclusions of mafic volcanic rocks and hybrid patches along the contacts. Rhyolite of the Harbour Main Group 3.5 km southeast of Foxtrap has been altered by solutions, probably originating in the granite pluton, to a very fine grained assemblage of sericite, quartz and pyrophyllite (Papezik, Keats and Vahtra, 1978).

Diabase and gabbroic dykes, sills and stocks are numerous and are feeders to Proterozoic and Paleozoic volcanic rocks. The Whalesback Gabbro (Williams and King, 1979) is a uniform, medium to coarse grained massive pyroxene-plagioclase rock and is possibly an intrusive equivalent of the local pillow lava of the Biscay Member of the Drook Formation. Spread Eagle Peak (to the south of the highway, near Chapel Arm) is a plug of gabbro intruded into Cambrian sediments and may have been a feeder to the Middle Cambrian pillow basalts exposed, together with associated fossiliferous black shales, along the shore of Chapel Arm.

Mafic sills at Point Lance have been dated by Krogh at 425± Ma (U-Pb-Zircon). The dykes of Cape St. Mary's are lithologically comparable with those in the Bonavista Peninsula region and may be possibly of the same age (circa 340-400 Ma).

2.2.4 Structure and Metamorphism

Avalonian and Acadian Orogenesis

The Avalon Zone in Newfoundland was first deformed in the late Precambrian Avalonian Orogeny and subsequently regionally deformed and metamorphosed during the mid-Paleozoic Acadian Orogeny. Evidence of Precambrian deformation is found mostly on the Avalon Peninsula; elsewhere in eastern Newfoundland the metamorphism and deformation has been attributed to Acadian orogenesis (e.g. Dallmeyer et al., 1983).

The effects of Acadian deformation and metamorphism are variable, but are most pronounced west of the Isthmus of Avalon. Metamorphism within the western Avalon Zone occurred under prehnite-pumpellyite to mid-greenschist facies conditions. The intensity of the Acadian tectonothermal event is greatest adjacent to the Dover-Hermitage Bay Fault (Blackwood and Kennedy, 1975). In contrast, much of the

Avalon and Bonavista Peninsulas have undergone only prehnite-pumpellyite facies metamorphism (Papezik, 1974).

Evidence of late Paleozoic deformation is scanty. Williams, 1971, Strong et al., 1978b, and O'Brien et al., 1983 have documented from the Burin Peninsula small scale faulting and open warps of Upper Devonian and Lower Carboniferous rocks, possibly related to Hercynian aged deformation. A major positive aeromagnetic anomaly - "The Avalon Magnetic Lineament" - a possible continuation of the Triassic dike system of New Brunswick and Nova Scotia, crosses the Avalon Peninsula in a northeasterly direction from St. Mary's to Tors Cove (Papezik et al., 1975, 1980); diabase dykes along the anomaly have been dated at 200 Ma.

Unconformities

Numerous pre-Tommotian unconformities provide evidence of late Precambrian folding, block-faulting, granitoid emplacement and general crustal instability (e.g. McCartney, 1967; Anderson et al., 1975; King, 1980, 1982). The now classic example is the Manuels River Unconformity with Cambrian strata covering an erosional surface above 620 Ma Holyrood Granite and the Harbour Main and Conception Groups. The angular unconformity at Bacon Cove, Conception Bay, between Cambrian strata and the Conception Group, provides

clear evidence of Precambrian deformation. The poorly exposed Musgravetown Group - Connecting Point Unconformity on the Isthmus of Avalon, is interpreted as recording local tectonic readjustments and not as a reflection of the more penetrative, regional Precambrian orogenesis in the Avalon Zone of Maritime Canada (Dallmeyer, et al., 1983). Nevertheless, the more significant unconformities including the Lilly Unconformity at Red Head (Fig. 6), are indicative of a major late Precambrian crustal uplift.

Folds

The Precambrian rocks of the Avalon Peninsula are open to tightly folded, depending upon lithology and bed thickness. Broad elongate domes and basins with near vertical north-northeast trending, axial surfaces, and with associated doubly plunging parasitic folds are typical of the structural style. Axial planar cleavage varies from vertical to steeply southeast to northwest dipping (Williams and King, 1979).

Examples of various styles of folding can be seen around St. John's. East of the harbour, thick-bedded red sandstone and conglomerate of the Cuckold Formation form the western limb of an open northward plunging syncline and reappear on the eastern limb at Cape Spear National Historic Park (Fig. 2.5). Monoclinal folds form spectacular cliffs east of

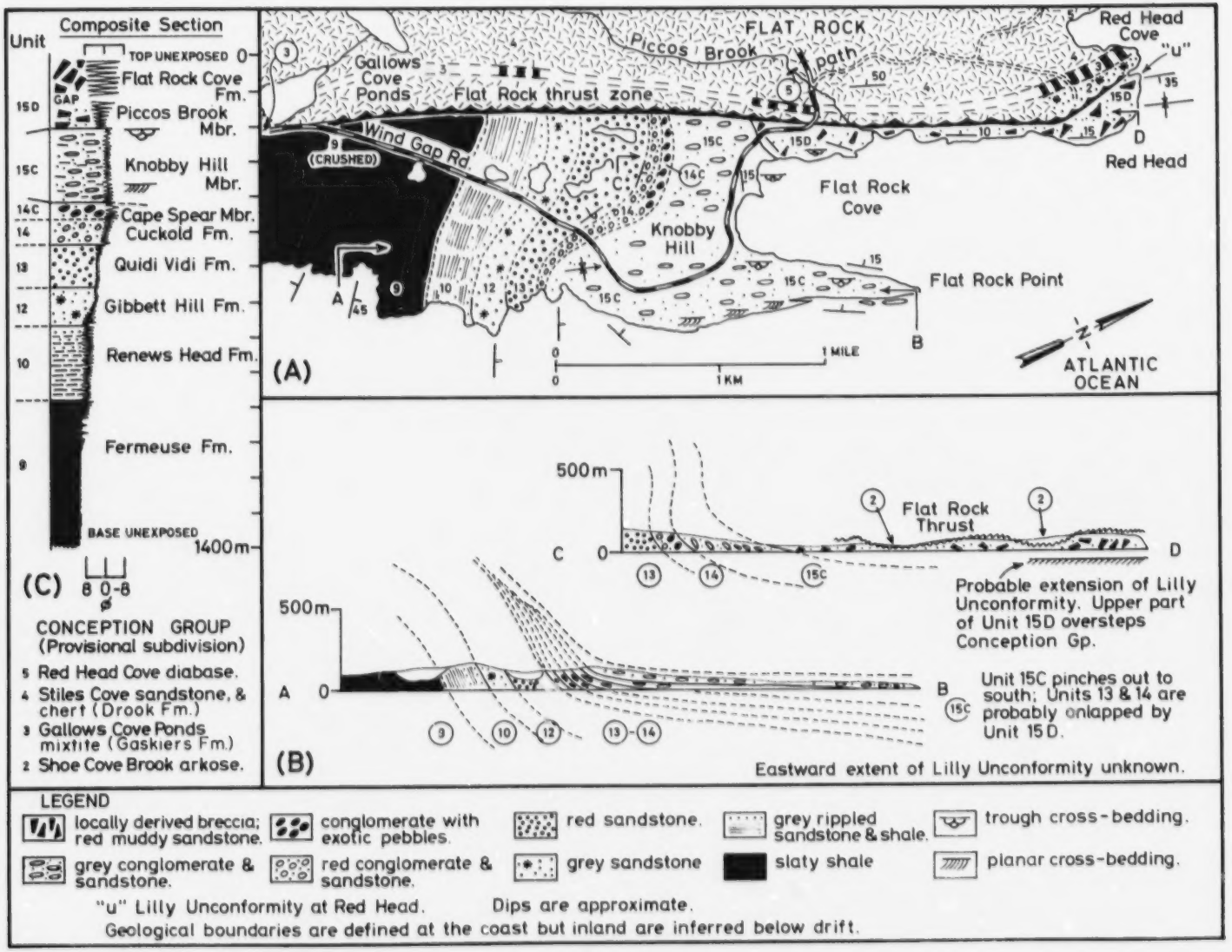


Figure 2.6 Geology of the Flat Rock area (after King, 1982).

Flatrock Cove (Fig. 2.6). The coastal cliffs around Torbay show numerous open to tight folds in greenish grey tuffaceous marine sandstone and siltstone of the Drook Formation; these parasitic structures form the core of the Tor Bay Anticline (Fig. 2.5).

Distinctive lithic units of the Conception and St. John's Groups clearly delineate the form of major folds elsewhere on the Avalon Peninsula. As suggested by Williams and King (1979) the open folds are possibly precursors of tighter structures and result from warping and decollement above a resistant substratum as might be provided by the Harbour Main volcanics.Continued compression would produce tighter folds with coplanar cleavage about consistent northeast-trending axes. Slaty cleavage, non-coplanar with the axial surfaces of folds is probably more widespread throughout the Avalon Peninsula than has heretofore been recognized.

Joints

Numerous fractures and joints are evident in virtually all rock units present on the Avalon Peninsula. Irregular or curvi-planar fractures are commonly parallel to axial surfaces in tightly folded rocks and are associated with fault zones and splays. Many are mineralized, for example,

quartz-calcite-bornite veins occur in Signal Hill sandstone near Petty Harbour (Rose, 1952) and major concentrations of pyrophyllite are confined to local shear zones near Manuels (Papezik, Keats and Vahtra, 1978).

Joints are conspicuous in well-stratified coarse clastic rock units such as the Signal Hill, Bell Island and Wabana Groups. Rhombohedral joint systems are recognizable in these units and probably developed perpendicular to the stratification during early stages of folding. Younger joint sets, such as can be seen on Signal Hill,tend to have low dips and are filled with milky quartz, very pale green to milky white prehnite, minor calcite and also occasional traces of copper minerals.

Faults

Throughout the Avalon Peninsula are numerous major strike-slip, normal and thrust faults (Figs. 1.1 and 2.2). The Topsail Fault Zone (Fig. 2.2) extends along much of eastern Conception Bay and separates Harbour Main volcanic rocks to the east from downthrown Ordovician sediments to the west. It merges with the Frenchman's Cove Fault (Fig. 2.4) which in the Fermeuse area is near vertical with its eastern side downthrown. The Peter's River Fault trends northeast from Peter's River to Holyrood, Conception Bay. Conception

Group rocks are crushed and broken where cut by the Peter's River Fault. In the Flat Rock area (Fig. 2.6), Conception Group rocks are thrust over highly fractured black shales of the St. John's Group exposed to the east; this structure, known as the Flat Rock Thrust Zone, is one of the best exposed thrust faults on the Avalon Peninsula.

2.2.5 Paleogeographic Evolution

Regional Tectonic Environments

Coeval lithofacies belts, faunal assemblages from equivalent habitats, and coeval tectonic elements, are three important lines of evidence leading to reconstructions of past environmental relationships.

The Avalon Zone of eastern Newfoundland is part of a Pan-African belt that was juxtaposed with the remainder of the Appalachian orogen during or after closure of the Paleozoic Iapetus Ocean (O'Brien et al., 1983; King and O'Brien,in press). The Avalon Zone in Canada may have evolved in a tectonic regime transitional between intraplate orogenesis (cf. Strong et al., 1978a; Strong, 1979) and continental margin tectonics (cf. Rast et al., 1976). The overall similarity in age, lithology, faunal assemblages and

tectonic history of the "Avalonian" and Pan-African belts imply that all evolved in similar tectonic environments.

The following model proposed for the early stages of structural evolution of the Canadian Avalon Zone, is summarized from O'Brien, et al. (1983). Sometime between 1000 and 800 Ma, prior to the Pan-African Orogeny, there were initial attempts to rift an Avalonian continential basement. During this period, totally ensialic flysch basins were formed and carbonate-clastic sediments were deposited (eg. Green Head Group of New Brunswick). Although these ancient deposits are not exposed on the Avalon Peninsula, the existence of basement rocks in the southeastern Caledonides and the eastern Appalachians provides indirect evidence that the underlying crust of the Avalon Zone of Newfoundland is continental. Continued attempts at rifting in the form of ductile spreading of the lower crust and upper asthenosphere over zones of high heat flow, locally resulted in partial melting and high grade metamorphism of the carbonate-clastic sequence. This event was followed or possibly accompanied by local complete crustal separation with the formation of submarine mafic volcanic, volcaniclastic, and comagmatic gabbroic rocks (the Burin Group) possibly through delamination of the lower crust (cf. Martin and Porada, 1977). Rifting was followed by closure of the locally developed ocean basins. Local and limited subduction, and

collision associated with crustal melting, produced the upper Proterozoic volcanic assemblages (eg. Harbour Main Group). This stage of orogenesis, including its termination, is well represented by the late Precambrian and early Paleozoic rocks of the Avalon Peninsula.

The Cambro-Ordovician stratigraphic record in eastern Newfoundland provides evidence of volcanicity and tectonism that may relate to the very early development of the Iapetus Ocean. The trilobite, acritarch and graptolite record links the Avalon Zone with the Anglo-Welsh area, western France and also Morocco. On faunal and sedimentary evidence, Cocks and Fortey (1982), in a reconstruction for Arenig to earliest Llanvirn times, showed a "Gondwanan" continent at high latitudes (circa 60-70 degrees south), embracing southern Britain, Armorica, Iberia, Bohemia, Morocco and eastern Newfoundland.

Evolution of The Avalon Peninsula

Schematic diagrams of the proposed evolution of the Avalon Peninsula (shown in King, 1980), reflect a long history of volcanic activity, uplift and subsidence. Facies relationships indicate an early history of widespread marine turbidite and pelagic sedimentation (Connecting Point - Conception Groups) around an active volcanic archipelago

(Harbour Main Group). The St. John's black shales record distal marine basinal sedimentation coeval with southward prograding deltaic sands of the Gibbett Hill Formation. Intermittent deposition of volcanic ash continued. Alluvial plain conditions developed and a rising mountain front on the northern periphery of the system gave rise to red sandstones (Maturin Ponds, Whiteway, Ferryland Head and Quidi Vidi Formations), conglomerates (Cuckold Formation) and variegated shales and sandstones (upper Signal Hill Group). The latest Proterozoic - early Paleozoic event was marked by pene-planation and transgression of the Cambrian sea with deposition of shallow marine sediments of the Random Formations. Subsequent Cambro-Ordovician sediments accumulated mainly as shallow marine and tidal deposits.

Geological events in the Avalon Peninsula are recorded in rocks up to about 200 million years ago. Extensive offshore oil exploration centered on the Grand Banks to the east and southeast of the Avalon Peninsula will no doubt complete the gap in knowledge of the geological history of the region up to the time of the last ice age.

3. HYDROGEOLOGY

3.1 Introduction

As shown in the previous chapter the Avalon Peninsula is underlain by volcanic, granitoid and clastic sedimentary rock units. These bedrock units are in turn overlain by a thin, discontinuous veneer of surficial materials that in general have a glacial/glacio-fluvial origin. Water well data for the surficial deposits are very sparse compared with that available for the bedrock units. Hence, while wells completed in surficial deposits outnumber wells completed in bedrock, the availability of data places the emphasis in this chapter on the hydrogeological characterization of the bedrock units.

Clastic sedimentary and crystalline rock masses consist of rock blocks bounded by discrete fracture planes. The clastic sedimentary bedrock units of the Avalon are well cemented and have very low matrix (primary) porosity and permeability, approaching those for most metamorphic and granitic rocks. Hence, at least in the near surface, fractures are the primary conduits for groundwater movement.

From a hydrogeological perspective the word fracture includes three main features; joints, fracture zones and shear zones (Fig. 3.1). Joints are discontinuous within their

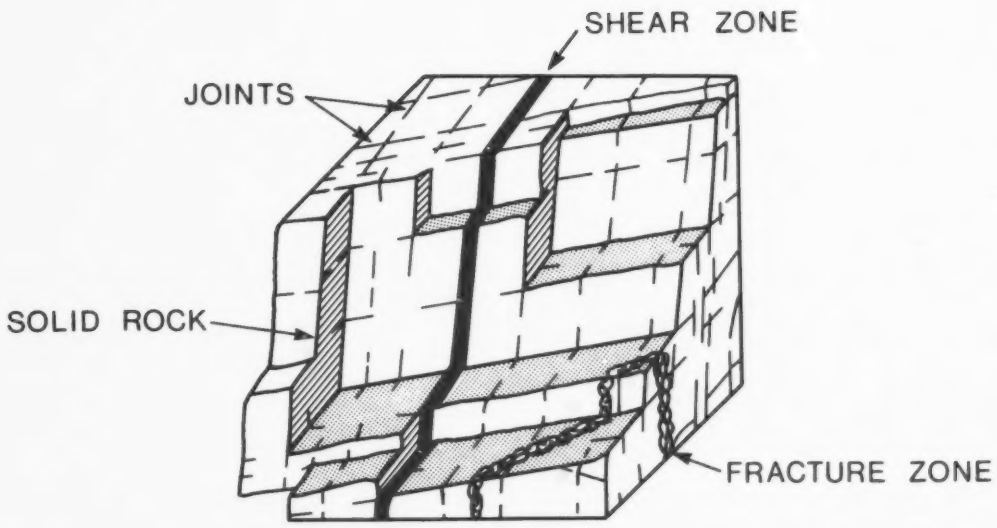


Figure 3.1 Conceptual model of the main flow paths in fractured rocks.

own planes but when the ratio of joint length to joint spacing is equal to or greater than one they generally form continuous networks for flow. In rock masses such as those found on the Avalon Peninsula, the hydraulic characteristics are predominantly a result of the interconnection of the different joint sets. In clastic sedimentary rocks, bedding planes, if open, form conduits similar to joints. Fracture zones are defined as zones of closely-spaced and highly-interconnected discrete fractures that are generally not filled with clay or any other material. Shear zones measure from less than a metre to tens of metres in width and are generally filled with broken and crushed rock. Depending on the rock type and the amount of shear displacement this material may be embedded in a clay matrix. Shear zones tend to be continuous throughout large parts of the rock mass, but may be either more or less conductive than the the rock mass, depending on infilling materials, cementation, age and stress. Large-scale features can extend for tens of kilometres but their hydraulic properties can vary considerably over such distances. There are complete transitions among these three classes of fractures.

In developing groundwater supplies from drilled wells in bedrock it is desirable to intersect a permeable shear or fracture zone or a zone of intense jointing. However, as shown in Figure 3.2, preglacial fracturing has rendered

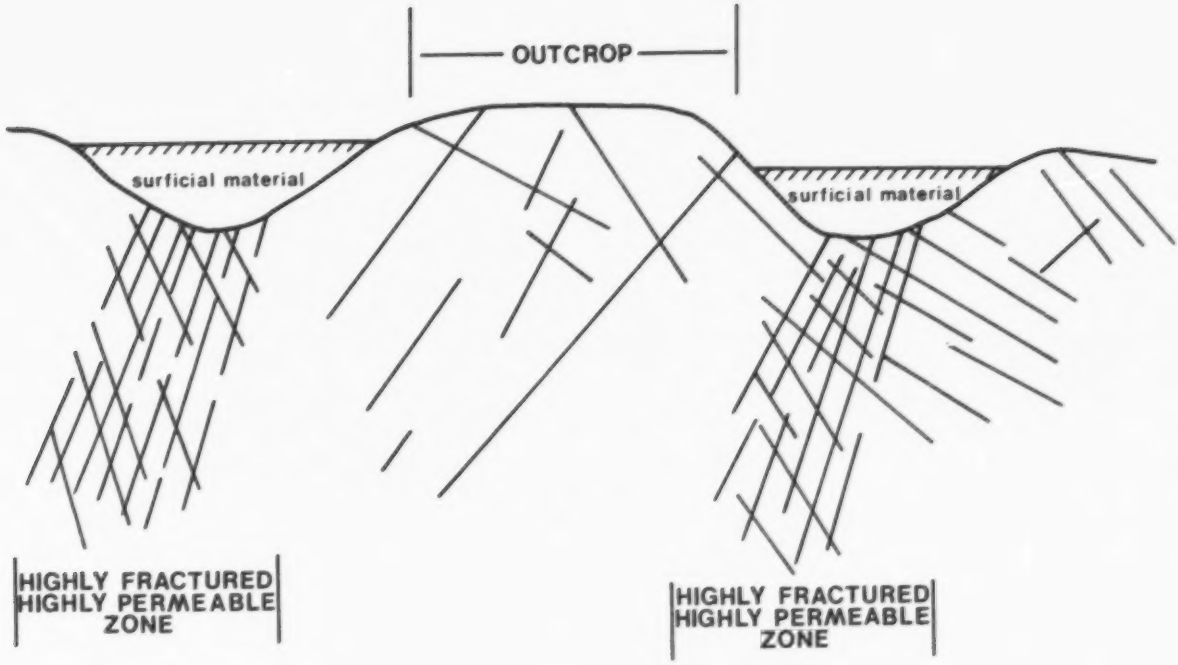


Figure 3.2 Cross section with regularly fractured rock forming outcrops and the more fractured and hence more permeable bedrock forming depressions filled by surficial materials.

bedrock susceptible to glacial erosion. Hence in glaciated terrains the highly fractured areas of bedrock tend to be differentially eroded and form depressions. These depressions were subsequently filled with surficial material, thus obscuring those areas that, locally, have the greatest groundwater potential.

In evaluating the groundwater potential of a given area it would help if one could determine if individual wells are located in fault or shear zone features or in regularly jointed rock. In this study, data on the location of individual wells did not provide sufficient information to determine the nature or degree of bedrock fracturing at the well locations. Hence the water well data available for this study have been examined in order to determine the hydrogeologic characteristics of the "rock-masses" or fractured bedrock units as a whole and not those of the individual structural features. Also the water well data have been examined to determine the hydrogeologic characteristics of the major surficial deposits.

3.1.1 Sources of Data

The Newfoundland Department of Environment, Water Resources Report 1-1 - "Water Well Data for Newfoundland 1950-1977" was the main source of data, in the form of water

well records, for this report. Additional records covering the post 1977 period were provided from the files of the Department of Environment.

When complete, these well records provide information on well location, owner, date drilled, elevation, well depth, depth at which water was found, casing length and diameter, static water level, yield, water quality, usage and the thickness and description of the overburden and bedrock. A total of 1,976 well records were examined during this study. Rather than merely reproduce these records in the form that they were provided by the Newfoundland Department of the Environment, we have summarized (Appendix B) the well data for each community in the form of averages and ranges for well depth, casing length, static water level, yield and overburden thickness (and description if available). For each community the bedrock geology map was used to determine which bedrock unit(s) were intersected by the wells. To obtain data on individual wells the reader is referred to the original sources.

While wells completed in overburden material are thought to outnumber bedrock wells in this study area, very little data are available on such wells. Only 54 overburden wells were identified in all of the available water well records. Wells were classified as overburden wells when the casing

length equalled the well depth or when the overburden thickness equalled the well depth, a tenuous system at best but the only approach possible in this study.

As shown by Table 3.1 most of the documented overburden wells are located along the southeast side of Conception Bay, in an area of glacial outwash. The bedrock wells are distributed primarily along the coastal regions, reflecting the distribution of population. The total number of wells in each community, for which records exist, is tabulated in Appendix B.

3.1.2. Depth and yield of bedrock wells.

The main data base available for assessing the hydrogeologic characteristics of the bedrock units is the water well records. In the water well records each well is located by the community in which it was drilled. The underlying bedrock unit in which each well was completed was determined by reference to a 1:250,000 bedrock geology map (Map No. 2) and by reference to 1:50,000 topographic maps. Although a total of 1,976 well records were examined, only 1,152 well records contained both depth and yield data. Of these 1,152 wells only 608 wells could be confidently assigned to a specific rock unit or group (Table 3.2).

Table 3.1 Data for wells completed in overburden material, by district and community.

District Community	Well Depth, m	Casing Length, m	Yield L/min	Use	Comments
Bellevue					
Blaketown	18.9	18.9	13.7	Do	
Conception Bay South					
Upper Gullies	34.1	-	36.4	Do	
"	34.1	-	18.2	"	
"	27.4	-	9.1	"	
"	27.4	-	27.3	"	
"	27.4	-	18.2	"	
"	22.3	-	13.7	"	
"	36.9	-	68.3	"	
"	16.8	-	13.7	"	
"	16.8	-	27.3	"	
"	12.2	11.27	45.5	"	
"	15.2	15.2	9.1	"	
"	17.7	17.7	18.2	"	
"	17.7	17.7	13.7	"	
"	18.3	18.3	91.0	"	
"	20.7	20.1	91.0	"	Sand and boulders
"	30.5	30.5	68.3	"	Sand and boulders
"	22.9	17.7	54.6	"	
"	13.4	10.4	36.4	"	Gravel and boulders
"	26.2	26.2	29.1	"	
"	26.8	26.8	18.2	"	
Foxtrap	15.2	-	18.2	"	
Kelligrews	18.3	-	11.4	"	
"	18.3	-	9.1	"	
"	25.9	-	13.7	"	
"	22.9	22.9	34.1	"	
"	33.5	33.5	18.2	"	
"	18.3	20.1	11.4	"	
"	18.3	-	36.4	"	
"	16.5	17.1	18.2	"	
"	65.5	-	9.1	"	
"	20.1	20.1	22.8	"	
"	20.1	20.1	18.2	"	
"	16.5	16.5	54.6	"	
"	16.8	16.8	5.7	"	

Table 3.1 Continued.

District Community	Well Depth, m	Casing Length, m	Yield L/min	Use	Comments
Manuels	18.3	18.3	13.7	"	
"	33.5	33.5	18.2	"	
"	30.5	30.5	13.7	"	
"	12.8	12.8	36.4	"	
"	38.1	38.1	54.6	"	
"	9.5	9.5	45.5	"	
Paradise	20.1	20.1	27.3	"	
Ferryland Cape Broyle	20.1	20.1	136.5	"	Poor quality
Harbour Main- Bell Island Salmonier Line	13.7	-	9.1	"	
"	9.1	-	18.2	"	
Kilbride Kilbride	12.2	11.3	36.4	Co	
Mt. Scio St. Philips	13.7	12.2	68.3	Do	
Port de Grave Georgetown	13.7	13.7	159.3	Do	Sand and gravel
Riverhead	8.5	-	182.	Mu	
"	11.0	-	182.	Mu	
St.John's East Extern Airport Road	10.7	-	27.3	Do	
St. Mary's- The Capes Bramen	10.1	10.1	136.5	Ind	Sand and beach rocks

Table 3.2 Distribution of wells in terms of bedrock units.

Rock Unit/Group	Rock Type	No. of Wells	Well Yield (L/min) Mean	Range
Harbour Main Group (1a,1b,1c,1d)	Volcanics, sedimentary, silicic intrusions.	74	24.5	1.1-136.5
Holyrood Granite (2,3)	Granite, Granodiorite, Quartz Monzonite, Gabbro.	22	27.6	2.3-136.5
Conception Group (4,5,6,7,8)	Siliceous sandstone, shale, siltstone, tuff tillite,volcaniclastics	211	20.4	0.6-136.5
St. John's Group (11,12,13)	Sandstone, shale, slate.	92	26.2	1.1-227.5
Bull Arm Group (14)	Tuffs, breccias, flows, siltstone.	3	34.8	4.55-91.0
Signal Hill Group (15,16,17,18,19,20)	Breccia, conglomerate sandstone, siltstone, shale, tuff.	18	43.0	1.1-273.0
Dildo Group (22,23,24)	Conglomerate, sandstone and shale.	18	16.9	4.6-68.3
Random, Bonavista, Smith Point,Brigus, Chamberlains Brook, Manuels River, Elliot Cove Formations. (26,27,28,30)	Shale, slate, limestone, quartzite conglomerate, arkose, siltstone.	156	27.4	1.1-364.0
Wabana Group and Bell Island Group (32,33)	Sandstone, siltstone, shale.	14	73.5	6.8-273.0

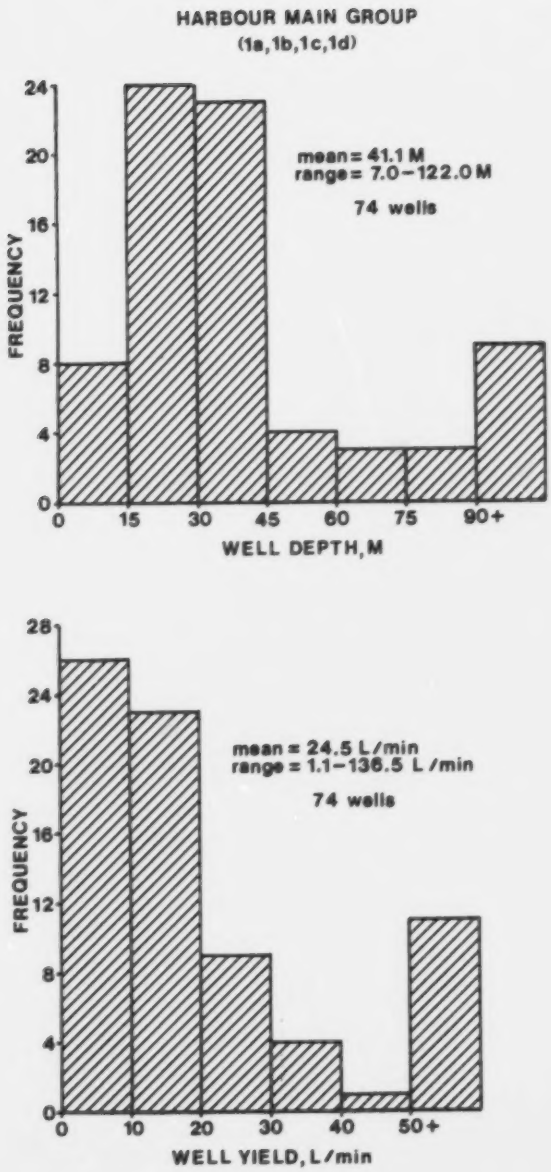
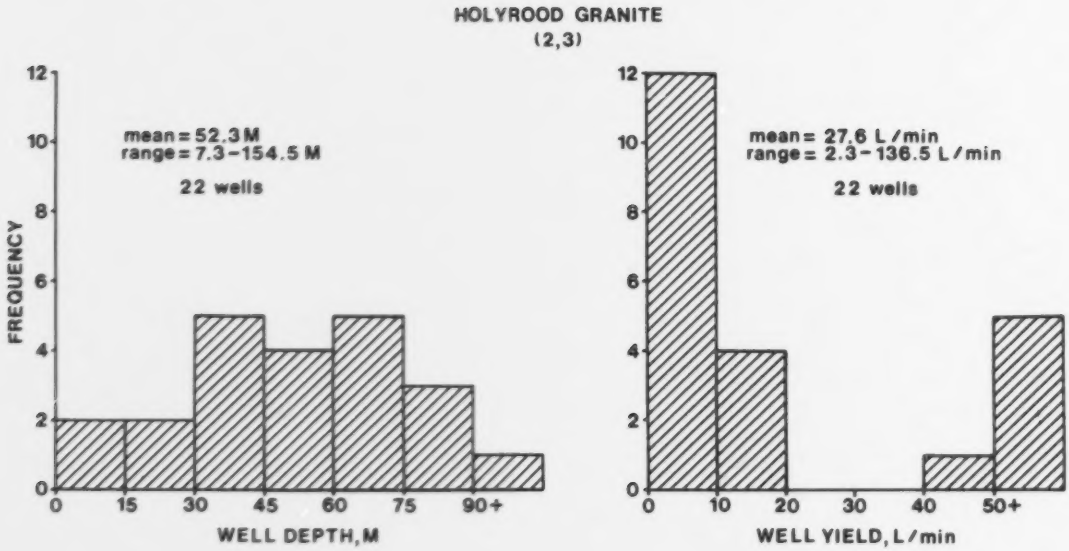


Figure 3.3 Frequency histograms for well depths and well yields for each bedrock grouping.



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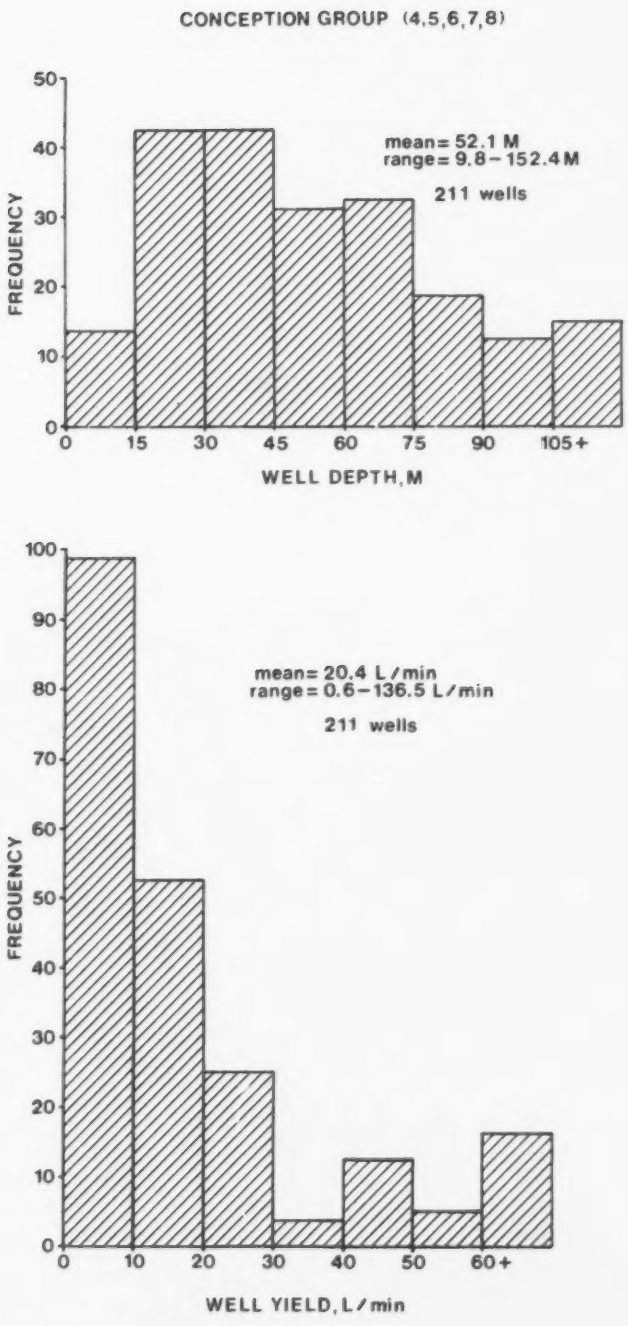

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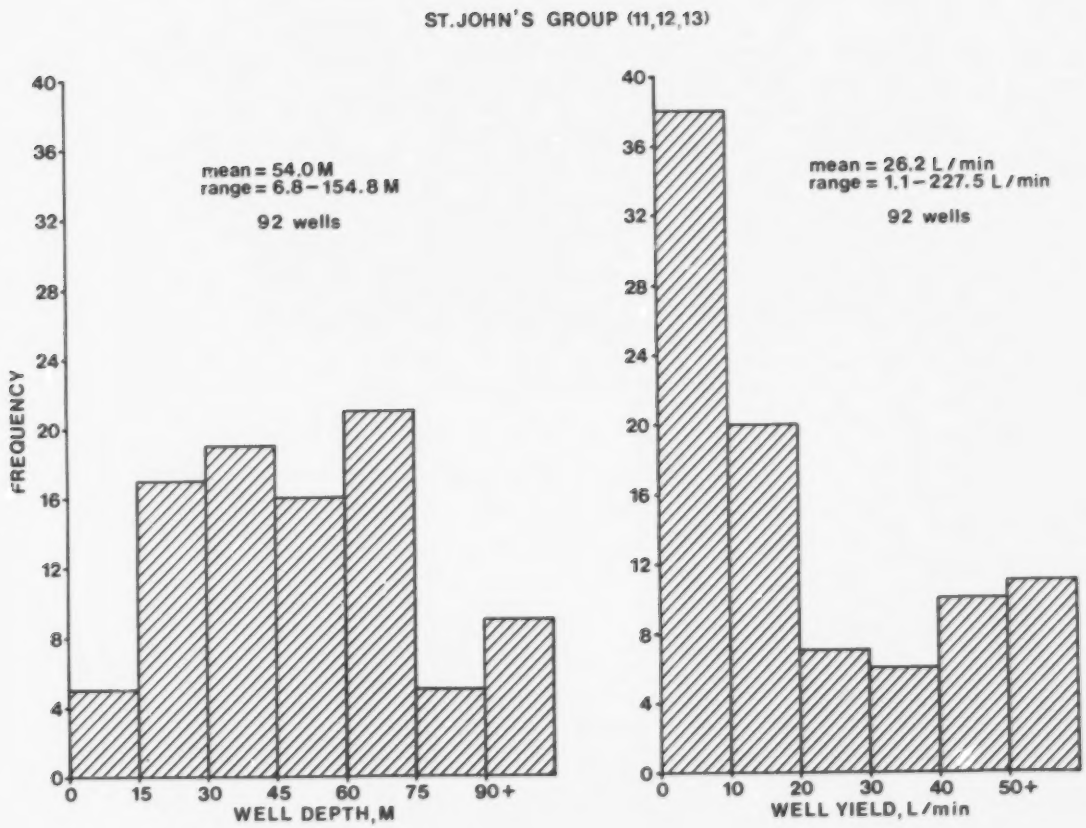

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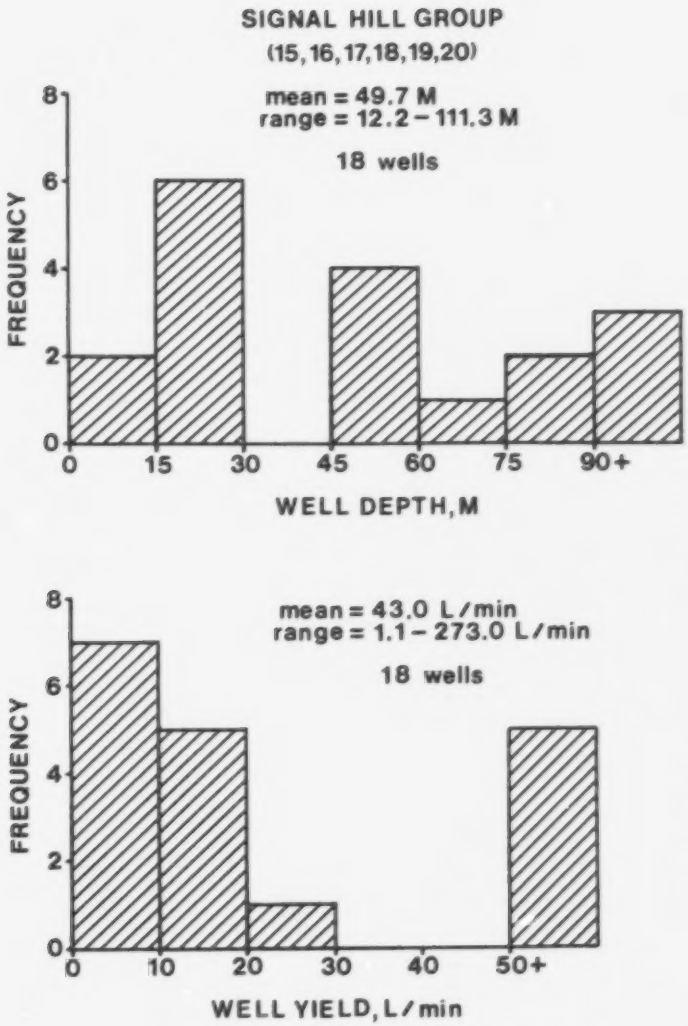

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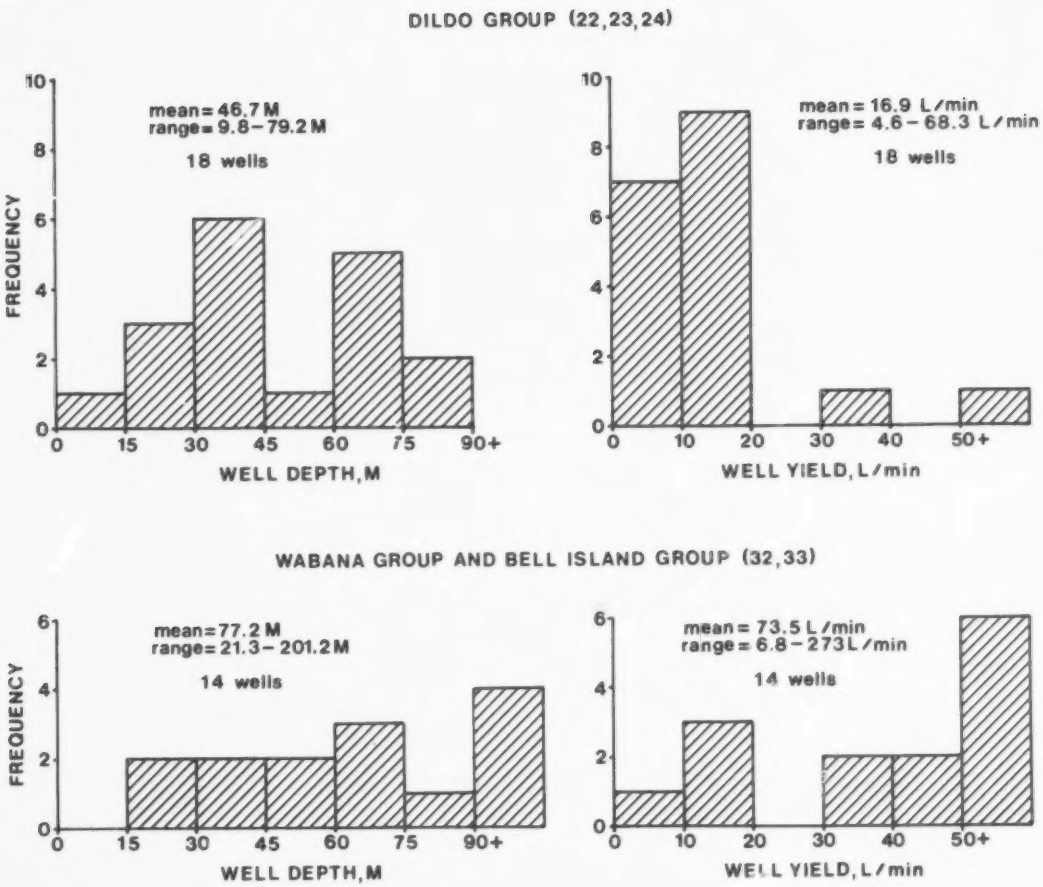


Figure 3.3 Continued.

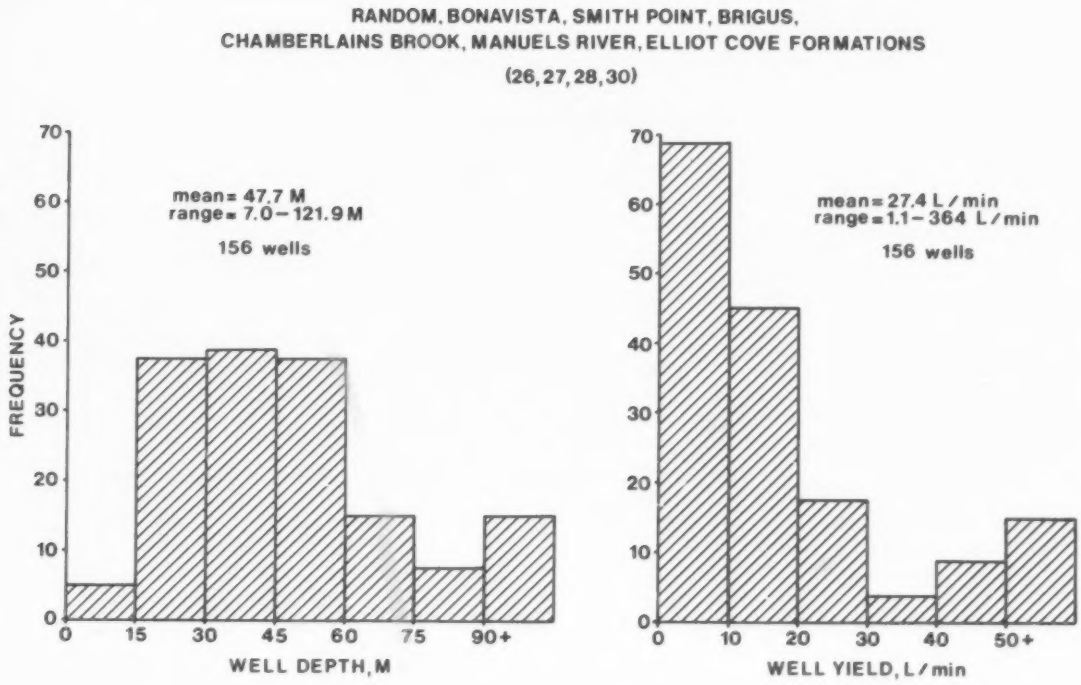


Figure 3.3 Continued.

Table 3.3 Raw statistics for well depth and well yield, for selected rock units.

Rock Unit	Well Depth, m Mean	St. Dev.	Well Yield, L/min Mean	St. Dev.
Harbour Main Group	41.1	28.7	24.5	26.6
Conception Group	52.1	30.6	20.4	23.5
St. John's Group	54.0	28.3	26.2	35.8
Formations 26,27,28,30	47.7	25.5	27.4	57.9

The distribution of well depths and well yields for each bedrock grouping in Table 3.2, are shown in Figure 3.3. All of the well depths greater than 90 m and well yields greater than 50 L/min are grouped in the last interval of each histogram. Figure 3.3 also gives both the mean value and the range of values for each bedrock unit. It is worth noting that while most of the frequency histograms of well depths can be approximated by normal distributions, nearly all of the frequency histograms for well yields are highly skewed. This observation is partly supported by the raw statistics, in terms of means and standard deviations, for selected bedrock groupings (Table 3.3). In the examples given in Table 3.3 the standard deviation values for well depths are less than the mean values whereas the well yield data show mean values less than the corresponding standard deviations.

The skewness of the frequency histograms for well yield suggests a logarthmic relationship between well depth and well yield. Hence in Figure 3.4 we have shown the well depth versus well yield data, for four of the main bedrock groupings, on log-log plots. While there is considerable scatter in the data there is an overall trend of decreasing yield with depth. The straight line on each plot is the regression fit to each data set. The equation of each line is also given on each diagram, in both feet (ft) versus gallons per minute (gpm) and metres (m) versus litres per minute

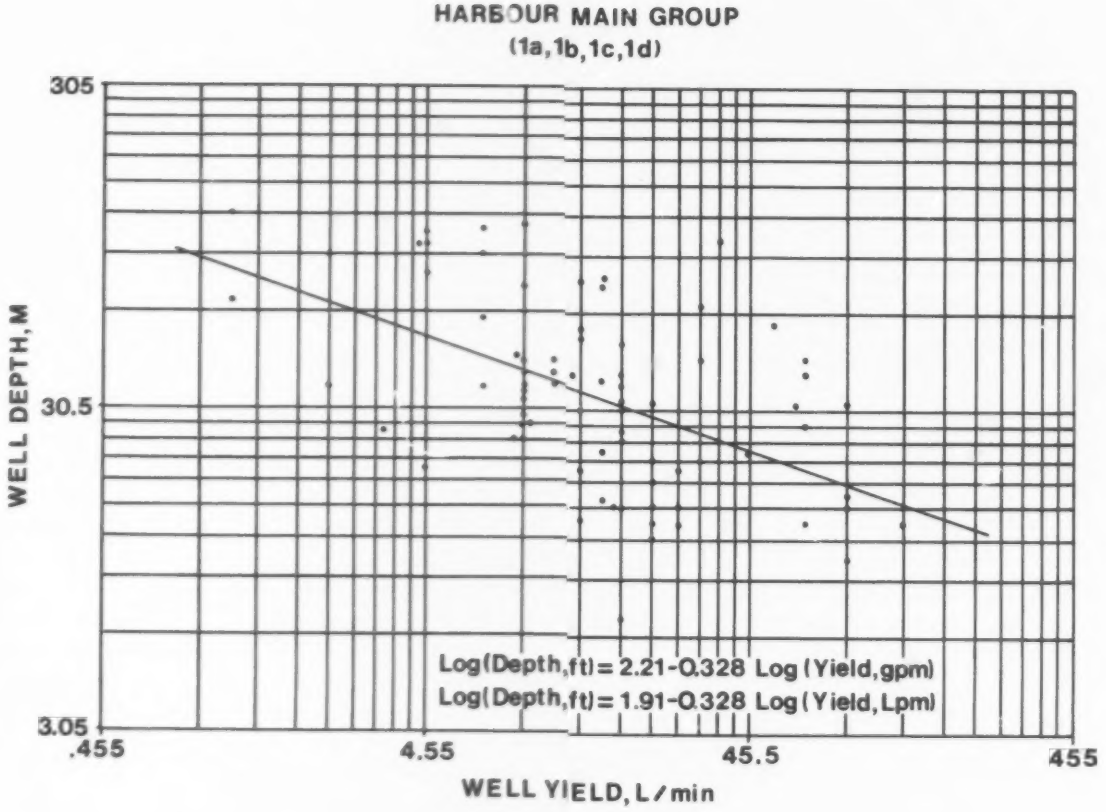


Figure 3.4 Relationship between well depth and well yield for four of the major bedrock groupings.

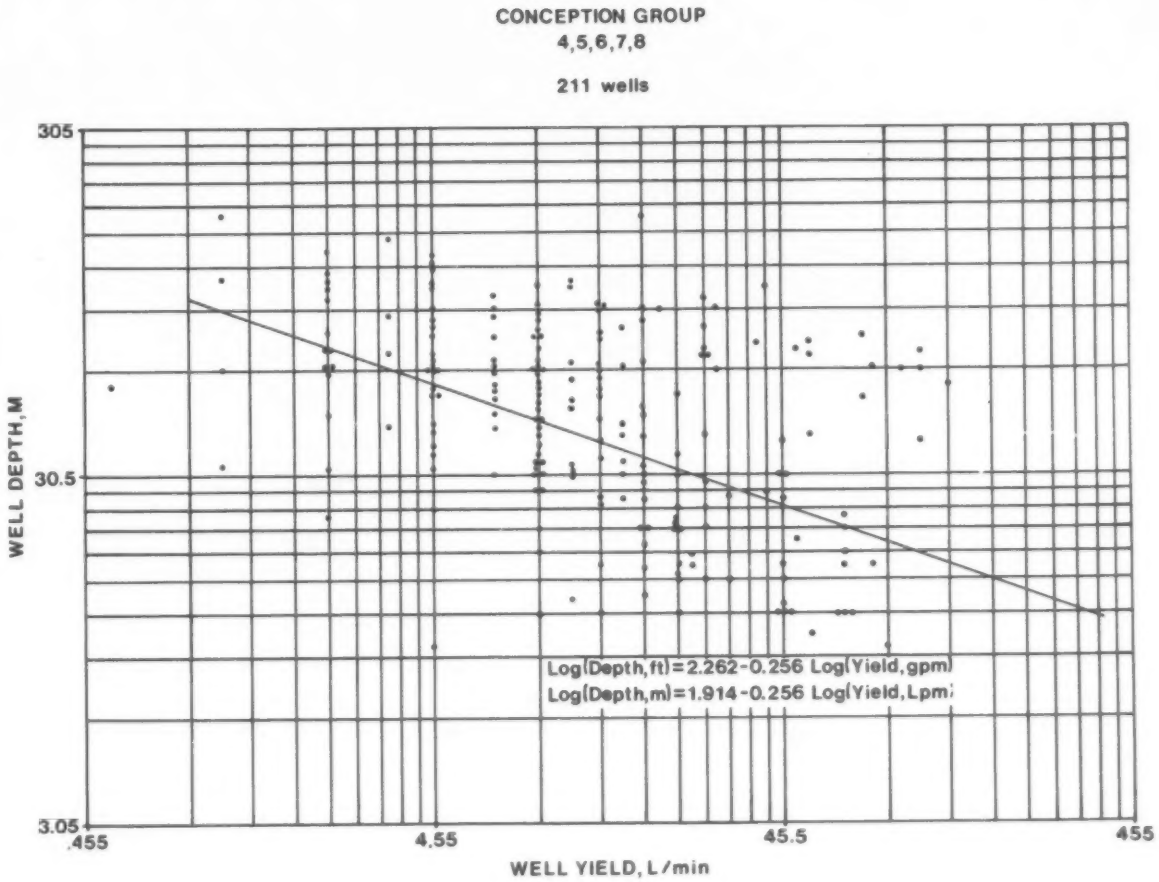


Figure 3.4 Continued.

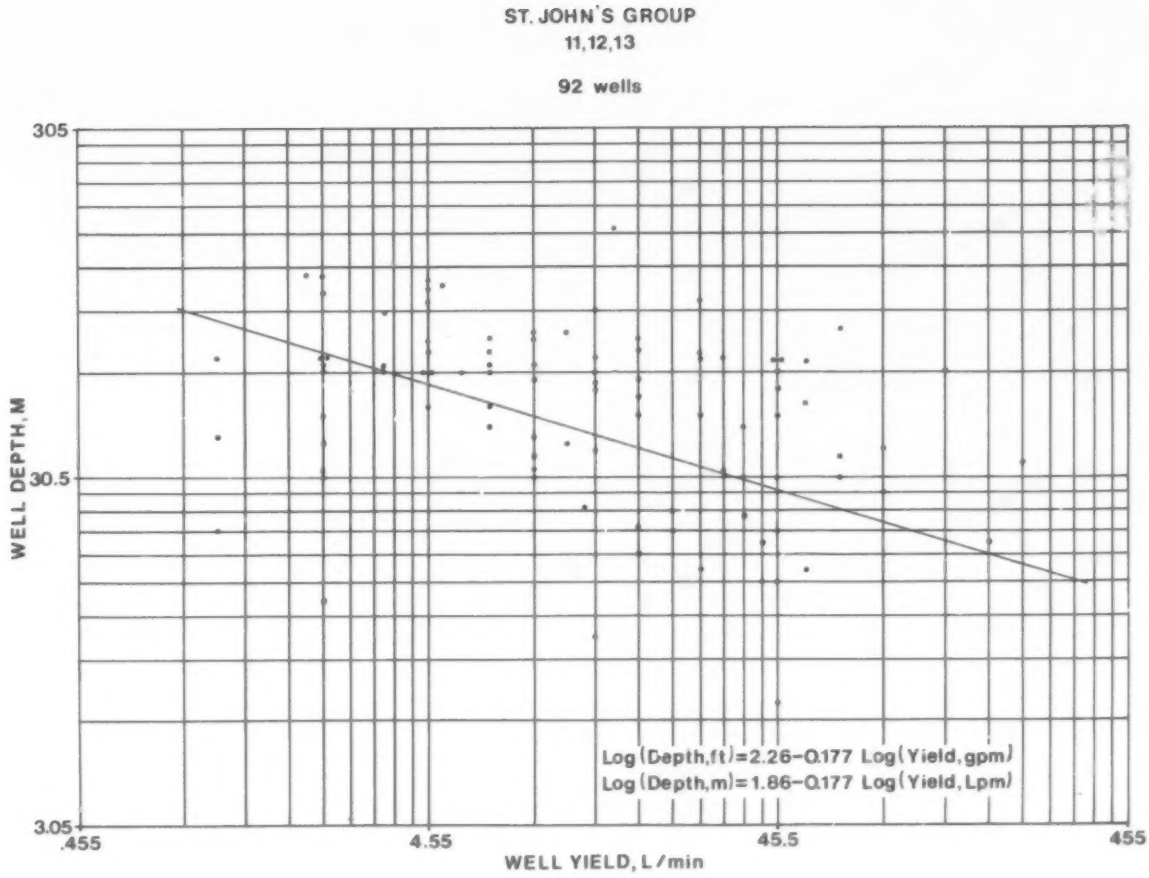


Figure 3.4 Continued.

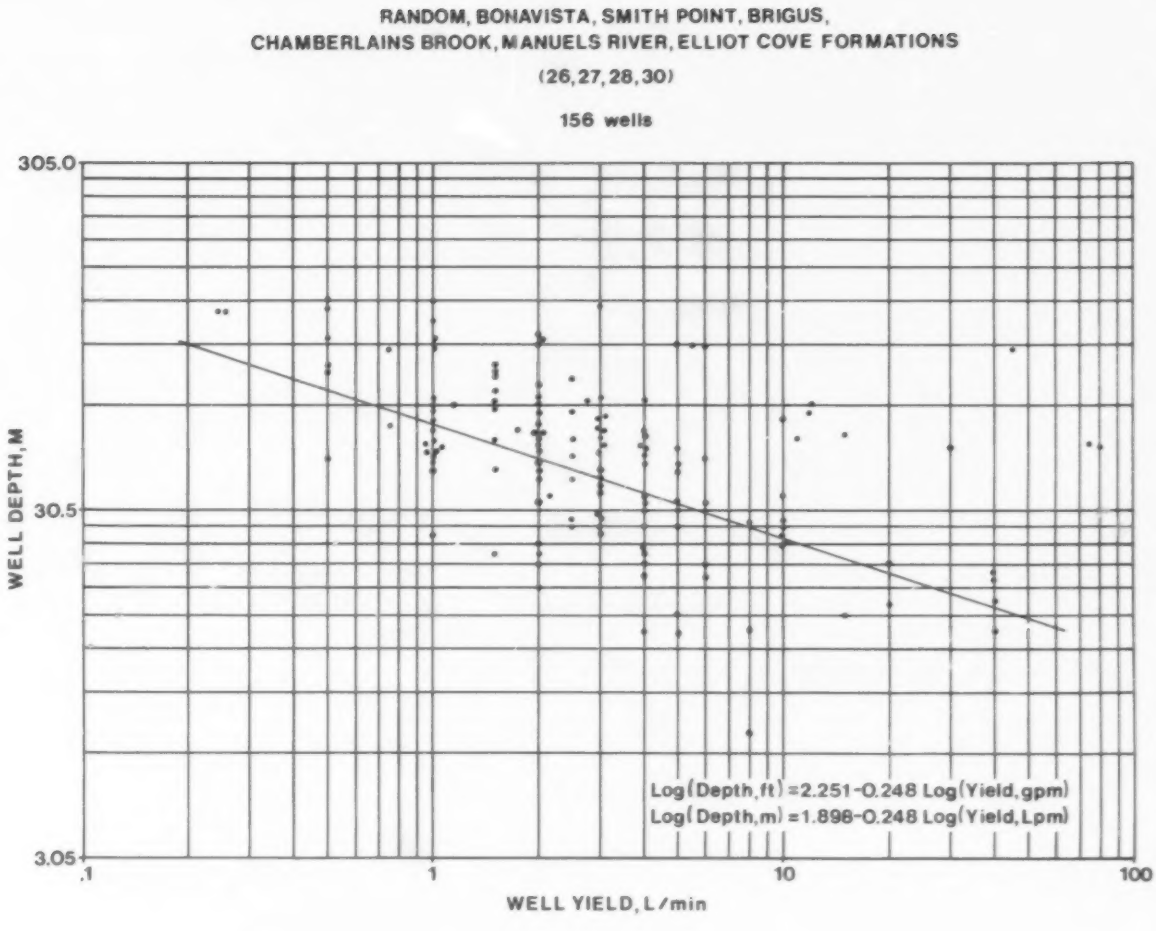


Figure 3.4 Continued.

(Lpm) units. The slope of the line, relating well depth to well yield, varies from -0.328 for the Harbour Main Group to -0.177 for the St. John's Group - a substantial difference. If the data for each rock unit could be separated into those that were completed in fracture-shear zone features versus those that were completed in regularly jointed rock, these depth-yield trends would be much better defined.

3.1.3. Aquifer Tests

An additional and valuable source of data on both overburden and bedrock hydrogeologic characteristics is provided by aquifer tests that have been completed as part of evaluating community water supplies or as part of a specific engineering activity. While it is assumed that a considerable number of aquifer tests have been completed in the study area only sixteen tests were available from the files of the Department of Municipal Affairs and the Department of Environment. These test results are tabulated in Table 3.4.

Aquifer tests consist of pumping a well at a constant rate and noting the drawdown in the well that is being pumped and/or in nearby observation wells. In order to establish the long term safe yield of a well it is necessary to pump the well continuously for a period of about 72 hours or more. As shown by Table 3.4, while most of the aquifer tests are

Table 3.4 Aquifer test data.

Location	Pumping Rate Lpm	Range in Pump. Rate (Lpm)	Test Duration (Hrs) Pumping	Recovery	Est. Safe Yield Lpm	Well Depth m	Rock Type	Transmiss. T. m^2/min	Static Water Level m
Admiral's Beach Well No.3	-	-	-	-	50	12.9	6	-	-
Admiral's Beach Well No. 5	-	-	-	-	35	19.4	6	-	-
Blaketown	6.5	-	23	-	7	69.	17	1.2×10^{-4}	2.1
Brigus South	10.0	10.0-27.0	23	-	9	67	12	1.7×10^{-3}	9.4
Calvert	-	20-54	5	-	12	36	6	-	8.
Mackinsons,C.B.	22.5	22.5-32	21	-	30	93	6	6.4×10^{-4}	3.1
Marysvale	-	7.0-22	48	-	15 - 18	122	6	-	6.4
O'Donnell's	14.5	-	23	-	15	93	6	2.3×10^{-4}	9.3
Renews-Cappahayden	-	-	-	-	25	62	12	-	5.5
Waterford River Basin: Well 1526 Site A	9.5	Constant	24	4	10 - 15	26	12	3.0×10^{-3}	0.8
Waterford River Basin: Well 1529 Site B (Donovans)	3.0	Constant	5.5	3.5	1 - 2	32	12	1.1×10^{-4}	2.9
Waterford River Basin: Well 1527 Site C	9.6	8.7 - 10.2	24	3.5	8 - 10	37	12	1.4×10^{-4}	3.2
Waterford River Basin: Well 1531 Site D	8.2	Constant	21.7	3.2	8 - 12	19	12	3.0×10^{-4}	-
Waterford River Basin: Well 1522 Site E (Obser. well in bedrock)	17.7	Constant	2.5	0.5	8 - 12	25	12	1.4×10^{-3}	4.3*
Waterford River Basin: Site F	20.8	Constant	22.8	3.2	6 - 12	43	12	1.9×10^{-4}	0.3
Waterford River Basin: Well 1527 (Kilbride)	14.8	12.1 - 14.8	60.	22.3	6 - 10	107	12	7.1×10^{-5}	1.0

* Storativity S = 2×10^{-4}

poorly documented, one test was conducted for a 60 hour period, one for a 48 hour period, eight for about 21 to 24 hours, three for less than 6 hours and three tests did not indicate the pumping period. This lack of aquifer test data would be reduced in future studies if the agencies requesting aquifer tests also required that the test data be properly documented, interpreted and placed on file with the Department of Environment.

Six of the available sixteen aquifer tests were conducted on wells completed in the Conception Group. The average estimated safe yield reported for these six tests is 26 Lpm with a range of 14.5 to 50 Lpm. This average safe yield is higher than the average yield determined from the water well data, but given the limited number of aquifer tests versus water well records, this difference cannot be given any significance.

Nine aquifer tests were completed in the St. John's Group (Rock Type 11, 12, 13). The estimated average safe yield for these nine tests is 10.4 Lpm with a range of 1 to 25 Lpm. This is considerably lower than the average well yield of 26.2 Lpm (range of 1.1 to 227.5 Lpm) obtained from the water well records, reflecting the dominating influence of wellbore storage during the shorter periods of testing used to obtain the water well data. Transmissivity values

ranged from 7.1×10^{-5} to 3.0×10^{-3} m^2/min. The one storativity value of 2×10^{-4} indicates that the overlying surficial material acts as a confining layer, most likely a leaky one.

Considering the importance of aquifer test data to assessing the hydrogeologic characteristics of the aquifer system it is essential that more care be taken when conducting these tests. In conducting aquifer tests in fractured bedrock at low pumping rates it is usually very difficult to control the discharge rate over the test period. This problem would be eliminated if a constant-discharge control tank (construction details are available from the author on request) was used as part of the regular aquifer test equipment. Finally, there can be no substitute for longer test periods preceeded by step-drawdown tests to establish the optimum pumping rate.

3.2 Hydrostratigraphic Units

A hydrostratigraphic unit is defined (Fetter, 1980) as "a formation, part of a formation, or a group of formations in which there are similar hydrologic characteristics allowing for grouping into aquifers or confining layers". The purpose of such grouping is to provide the basis for a first approximation of the groundwater potential of a given area and to serve as a guide to developing the regional

groundwater resources. The difference between hydrostratigraphic units is much more significant and meaningful in areas with a wide range of permeabilities.

3.2.1 Surficial Deposit Hydrostratigraphic Units

In order to be consistent with the earlier Trinity Bay Area study (Water Resources Report 2-4) the surficial deposits within the Avalon Peninsula study area have been divided into two surficial hydrostratigraphic units. The distribution of surficial deposits within the study area is taken from Henderson (1972). Henderson's map shows only a few scattered occurrences of beach and bar deposits, most of which, because of their location, would be prone to sea water intrusion problems if subjected to heavy pumping. Modern stream deposits occupy a few scattered stream or river channels, with the largest deposits occurring along the lower part of the Salmonier River, near Branch and Harricott in St. Mary's Bay. The coastal areas, from Ferryland to Peter's River in St. Mary's Bay, and the southern half of the peninsula on the western side of St. Mary's Bay contain a number of eskers and meltwater channels (see Map No. 1). These features could very well be significant groundwater aquifers but there are no documented data on their groundwater potential. Given their widespread occurrence in the southern Avalon they may represent a considerable source

of groundwater and hence their potential should be assessed.

The southern Avalon also contains significant areas covered by bog and marsh, but these are not considered potential aquifers due to water quality problems. Hence the two main surficial hydrostratigraphic deposits are (1) moraine deposits, S1, (end moraine, hummocky moraine, ablation moraine, ground moraine with continuous cover and ground moraine with discontinuous cover) and (2) outwash deposits, S2, (gravel, sand and silt).

Hydrostratigraphic Unit-S1

Surficial Hydrostratigraphic Unit S1 consists primarily of ground moraines in the eastern, southern and western parts of the study area. In the central part of the study area between St. Mary's Bay and Conception Bay end moraine predominates (see Map No. 1). Because of the presence of these moraines over most of the study area, many dug wells are completed in these till deposits. The tills are dense and well-graded. Based on field observations and sieve analysis hydraulic conductivities of 10^{-7} to 10^{-10} m/sec are assumed, producing average yields of less than 9 L/min (Water Resources Report, 2-4). As with most low permeability aquifers, the well has to provide considerable storage to meet user demands.

Hydrostratigraphic Unit-S2

This hydrostratigraphic unit is believed to have the greatest groundwater potential of any of the hydrostratigraphic units in the study area. It consists of deposits of gravel, sand and silt representing primarily outwash plain deposits and to a lesser extent Kames. A half mile to mile wide outwash plain, representing the largest continuous body of stratified drift in the study area, extends from Seal Cove to Topsail Head, along the southern coast of Conception Bay. Other smaller fluvioglacial deposits are scattered throughout the study area (Figure 3.5).

Available data for the S2 hydrostratigraphic unit are tabulated in Table 3.5. While a mean yield of 40.6 L/min has been determined from the well records it may not indicate the true potential of this unit since many wells appear to produce from only the open end of the casing at the bottom of the well. There is little evidence to suggest that well screens or casing slotting is used extensively, if at all, in developing this surficial aquifer system.

3.2.3 Bedrock Hydrostratigraphic Units

Table 3.2 indicates that there are eight different

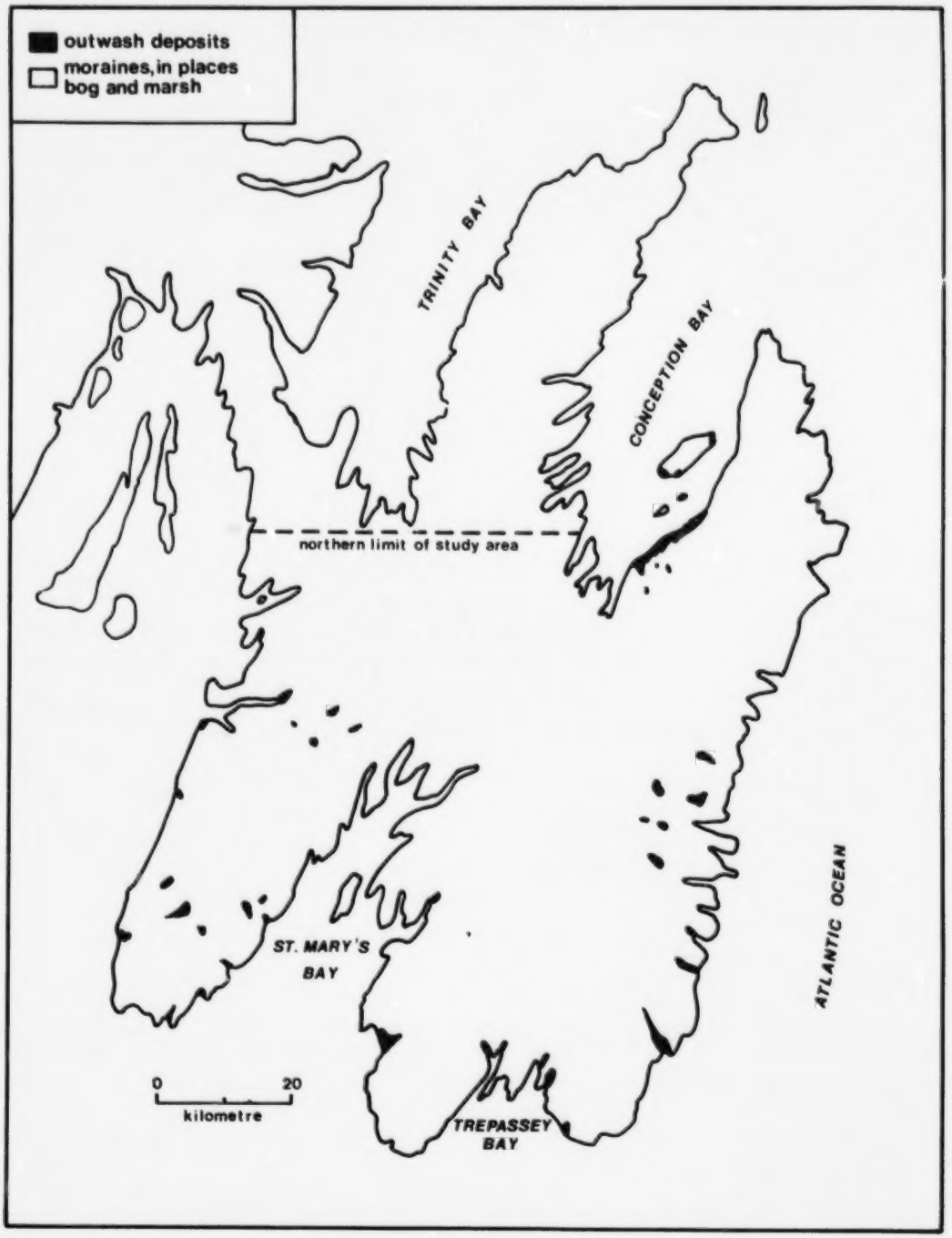


Figure 3.5 Distribution of main deposits of surficial hydrostratigraphic unit S2.

Table 3.5 Surficial deposit hydrostratigraphic units.

SURFICIAL HYDROSTRATIGRAPHIC UNIT	WELL YIELD L/min./(gpm) RANGE	WELL YIELD L/min./(gpm) MEAN	WELL DEPTH m/(feet) RANGE	WELL DEPTH m/(feet) MEAN	DATA SOURCE
UNIT S1 MORAINE LOW YIELD (2,3,4,5,6)**	0.0001-0.1* (0.0005-0.5)	<9.0 (<2.0)	N.D.	N.D.	
UNIT S2	5.7-182. (1.25-40.)	40.6 (8.9)	8.5-65.5 (28-215)	20.9 (68.7)	2
OUTWASH DEPOSITS MODERATE TO HIGH YIELD (7)**	9.1-159.1 (2-35)		11.3-29.6 (37-97)		1

* Estimates, based on assumed hydraulic conductivities of 10^{-7} to 10^{-10} m/sec for a 2 m deep well, one metre in diameter with full drawdown. Data in brackets are in feet and Imperial gallons per minute.

** Numbers refer to surficial geology map units

Sources of Data

1. Hydrogeology of Trinity Bay Area. Water Resources Report 2-4, Newfoundland and Labrador Department of Environment

2. This report.

Sources of Information

1. Henderson, E.P., 1972: Surficial Geology of Avalon Peninsula, Newfoundland. Geological Survey of Canada, Memoir 368, and accompanying Surficial Geology Map, No. 1320A.

bedrock groups, formations or units for which both well depth and well yield data exists. The Bull Arm Group with only three wells is assumed to have insufficient data for further consideration. In addition the aquifer test results in Table 3.4 provide more data on the Conception, St. John's and Signal Hill Groups. As shown by Figure 3.3 and Table 3.2 the mean well yield values ranged from 16.9 L/min to 73.5 L/min. In order to be consistent with the earlier reports in this series, and based on individual domestic water needs, we have defined low yield as being less than or equal to 10 L/min, low to moderate yield being between 10 and 25 L/min, moderate yield ranging from 25 L/min to 40 L/min, moderate to high yield ranging from 40 to 60 L/min and high yield being greater than 60 L/min. The data on both mean well yield and the range of well yields were used in conjunction with basic geological data to define five bedrock hydrostratigraphic units (Table 3.6). The distribution of these units has been outlined on the bedrock hydrostratigraphic map (Map No. 3) and is shown on Figure 3.6.

Unit B, including the Conception and Dildo Groups, is classified as having low to moderate yield, the bedrock unit with the lowest mean productivity, based on 229 well records. The most productive unit, Unit E, includes the Wabana and Bell Island Groups. Unit E has a mean of 73.5 L/min with a range of 6.8 to 273 L/min based on 14 wells. The

Table 3.6 Bedrock hydrostratigraphic units.

BEDROCK HYDROSTRATIGRAPHIC UNIT	WELL YIELD L/min./(gpm) MEAN	WELL YIELD L/min./(gpm) RANGE	WELL DEPTH m/(ft) MEAN	WELL DEPTH m/(ft) RANGE
UNIT A MODERATE YIELD Harbour Main Group, Holyrood Granite (Volcanics, Sedimentary, Intrusive granitic rocks) (1a,1b,1c,1d,2,3)*	25.2 (5.5)	1.1-136.5 (0.25-30.)	43.7 (143.3)	7.0-154.5 (23.-507.)
UNIT B LOW TO MODERATE YIELD Conception, Dildo Groups (Siliceous sandstone, shale, siltstone, tuff, tillite, volcaniclastics conglomerate) (4,5,6,7,8,22,23,24)*	20.1 (4.5)	0.6-136.5 (0.13-30.)	51.7 (169.5)	9.8-152.4 (32.2-500)
UNIT C MODERATE TO HIGH YIELD Signal Hill Group (Breccia, conglomerate, sandstone, siltstone, shale, tuff) (15,16,17,18,19,20)*	43.0 (9.5)	1.1-273. (0.25-60.)	49.7 (163.1)	12.2-111.3 (40.-365.2)
UNIT D MODERATE YIELD St. John's, Random, Bonavista, Smith Point, Brigus, Chamberlains Brook, Manuels River, Elliot Cove Formations. (Shale, slate, limestone, quartzite, conglomerate, arkose, siltstone sandstone) (11,12,13,26,27,28,30)*	27.4 (6.0)	1.1-364 (0.25-80)	47.7 (156.5)	7.0-121.9 (23.-400)
UNIT E HIGH YIELD Wabana and Bell Island Groups (Sandstone, siltstone, shale) (32,33)*	73.5 (16.2)	6.8-273 (1.5-60)	77.2 (253.3)	21.3-201.2 (70.-660.)
NC (Not Classified)				

* Numbers refer to bedrock geology map units.

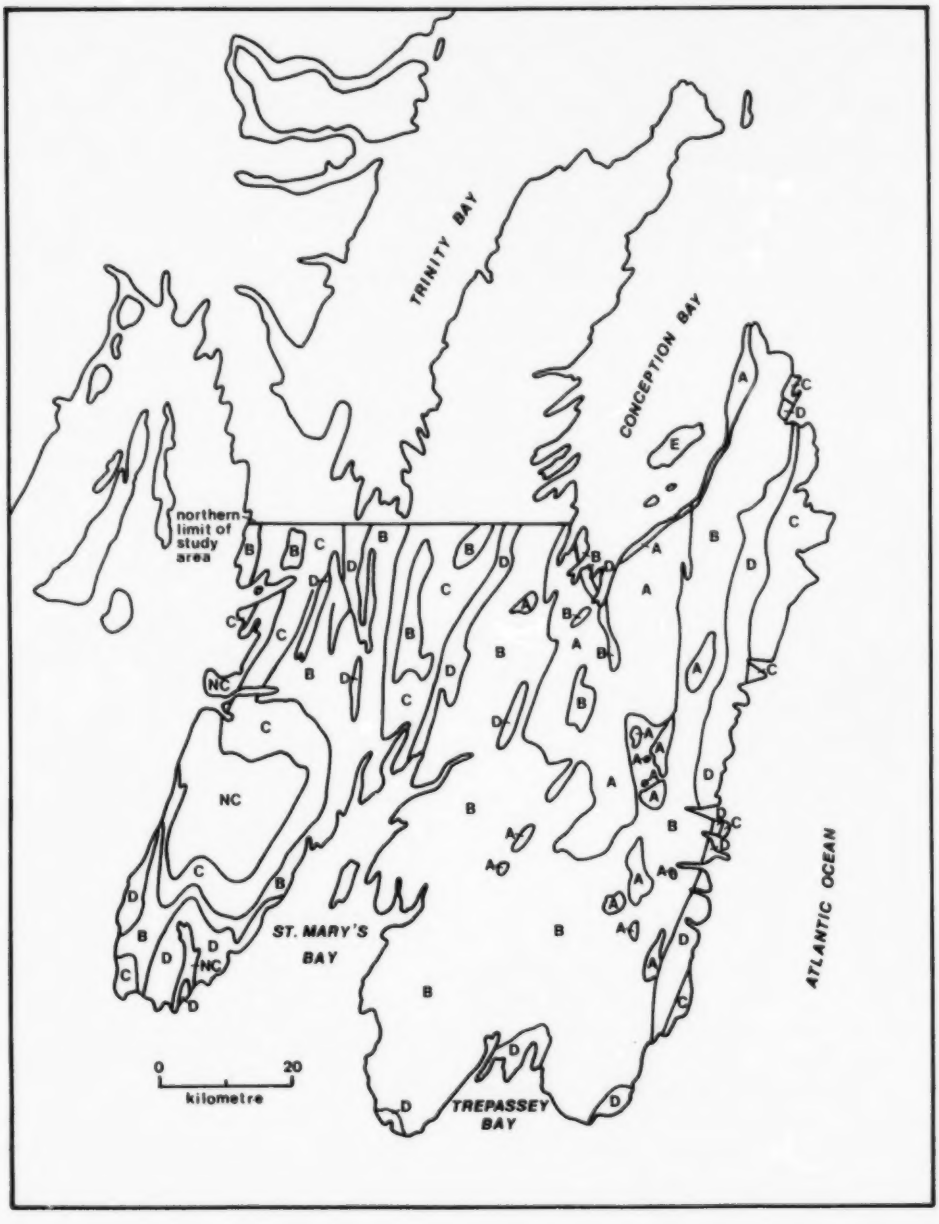


Figure 3.6 Distribution of bedrock hydrostratigraphic units. Description of each unit is given in Table 3.6.

justification for including in the same unit both shale, sandstone, conglomerate and siltstone is that we are dealing only with secondary porosity and permeability. Also the existing water well records make it difficult to decide in which part of a given rock group a particular well is drilled. However the above subdivision into five hydrostratigraphic units is an initial step in defining the general hydrogeologic characteristics of the bedrock units underlying the Avalon Peninsula.

3.3 Groundwater Flow Systems

Groundwater flow systems have been discussed by a number of authors (i.e. Fetter, 1980). It is generally accepted that topographic highs are areas of groundwater recharge and topographic lows are areas of groundwater discharge. In fractured bedrock with little to no matrix porosity and permeability very little is known about the configuration and nature of groundwater flow systems. Recent numerical modelling work by the senior author has demonstrated the importance of lakes and ponds in controlling the development of flow systems. Similarly, major fracture and shear zones, such as those that trend North-South through the central part of the study area, tend to have a major short-circuiting effect on the flow pathways. The lakes and ponds are thought to represent local and/or regional groundwater discharge

points. Groundwater discharge into lakes may very well be the source of the Uranium and Molybdenite anomalies (Davenport, P., 1984 - personal communication) in lake sediments in areas underlain by the Harbour Main volcanics and the Holyrood Granite.

As indicated in this and the previous chapter in this report, the Avalon Peninsula is characterized by a mantle of glacially derived material overlying fractured bedrock. The effect of this mantle of till on both recharge and discharge mechanisms in fractured bedrock and its role in modifying the groundwater flow system is poorly understood. However, we do know that recharge of the bedrock system often occurs through the till. Also we would expect to find younger, fast, flow systems in the tills and older, with longer flow pathways, flow systems in the fractured bedrock. The groundwater flux should be higher in the overburden and lower in the bedrock. Given the widespread use of dug and drilled wells for domestic water supplies, the till-fractured bedrock system should be the subject of more intensive investigations.

4. SURFACE WATER - GROUNDWATER HYDROLOGY

4.1 Hydrologic Budget

A hydrologic budget is a quantitative evaluation of water input and water output of a drainage basin over a given period of time. In its simplest form the annual hydrologic budget can be stated as

$$P = Q + E + \Delta S_s + \Delta S_g$$

where P is the precipitation, Q is the stream discharge, E the evaporation, ΔS_s the change in surface water storage and ΔS_g the change in groundwater storage. Over many years of record, or when ΔS_s and ΔS_g are negligible,

$$P = Q + E$$

The annual stream discharge (Q) is comprised of an overland stormflow component and a groundwater discharge component whose relative contributions depend on several factors including the physiography of the drainage basin, hydraulic parameters of the aquifer systems and spatial and temporal distribution of precipitation in the basin. The annual groundwater discharge or "baseflow" is approximately equal to groundwater recharge in the basin plus or minus any change in groundwater storage. Thus an evaluation of baseflow characteristics of streams can provide an estimate of groundwater recharge in the drainage basin.

An assessment of each parameter of the hydrologic budget as it relates to the Avalon Peninsula follows.

4.1.1 Precipitation

The locations of existing precipitation recording stations operated by the Atmospheric Environment Service of Environment Canada are shown on Figure 1.3. The mean precipitation value for the period of record at each station is given in Table 1.2. Annual precipitation values vary substantially across the Avalon even within a particular drainage basin. Inland portions of watersheds at higher elevations may, for example, be subject to much higher annual precipitation than coastal areas where most of the precipitation stations are located.

4.1.2 Runoff

Surface water quantity data for the Avalon Peninsula is published by the Water Resources Branch of Environment Canada. Figure 4.1 shows the locations of stream gauging stations currently operated and the drainage area for a number of the basins. Table 4.1 lists the gauging stations used in this study, their drainage area and period of record for each station. Stations with less than five years of

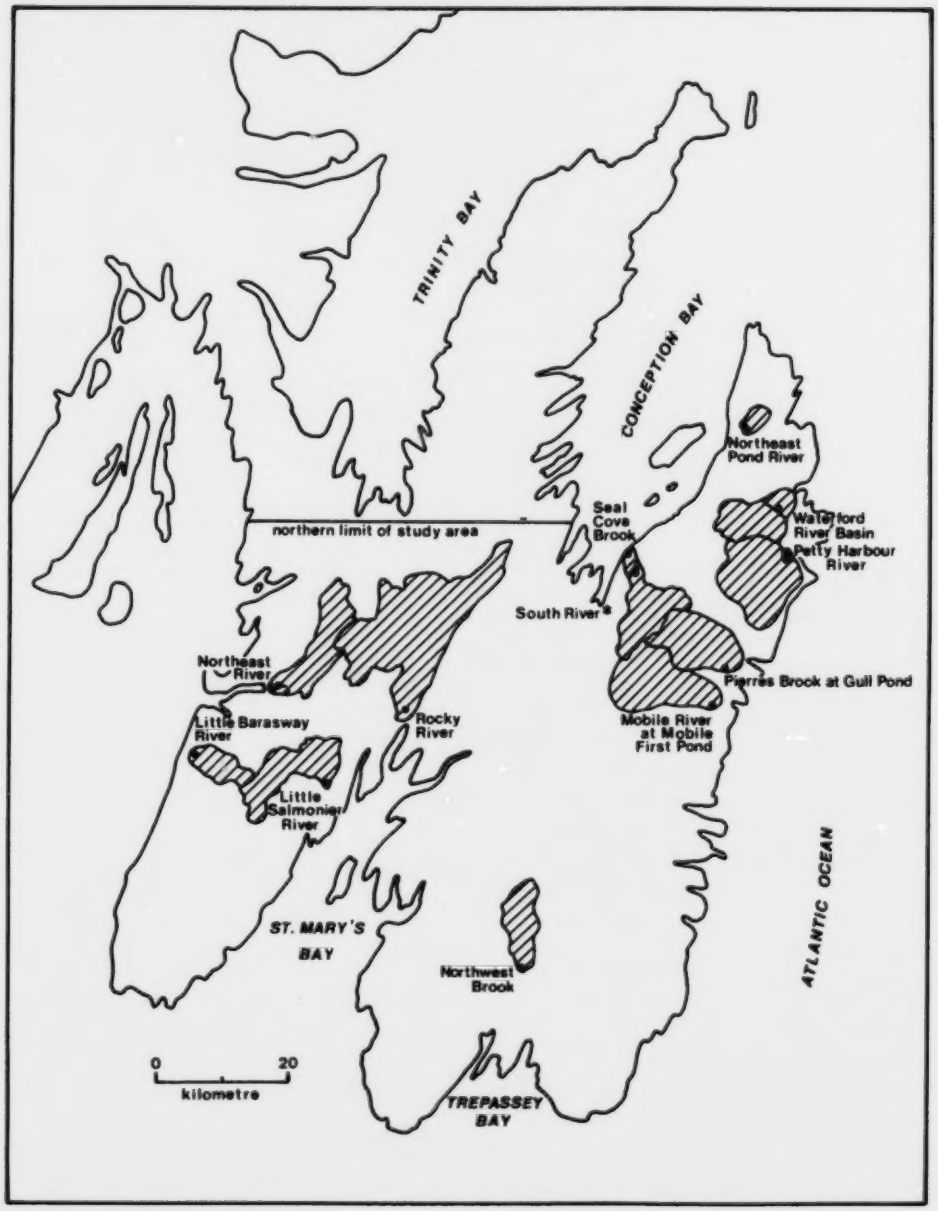


Figure 4.1 Location of hydrometric stations (solid dots) and outline of selected drainage basins (cross-hatching).

Table 4.1 Summary of Basin Yield Data, Avalon Peninsula.

Watershed	Drainage Area $(km)^2$		Mean Annual Yield $(m^3/s/km^2)$	Yield mm*	Period of Record
Mobile River at Mobile First Pond 02ZM003	112.0	(R)[1]	0.054	1688	1962-82
N.E. Pond River 02ZM006	3.63	(N)[2]	0.037	1171	1953-82
Northwest Brook at N.W. Pond 02ZN001	53.3	(N)	0.058	1841	1966-82
Petty Harbour River 02ZM001	134.0	(R)	0.044	1388	1962-82
Pierres Brook at Gull Pond 02ZM002	117.0	(R)	0.044	1376	1962-82
Rocky River at Colinet 02ZK001	285.0	(N)	0.040	1249	1948-82
Waterford River at Kilbride 02ZM008	52.7	(N)	0.041	1298	1974-82

[1]R = Regulated Flow [2]N = Natural Flow * mm on drainage basin

record have been omitted. On Table 4.1, streamflow in drainage basins of the Avalon is characterized in terms of mean annual basin yield; that is, the average discharge rate in each basin, normalized with respect to its drainage area. The adjacent column shows this value in terms of millimetres of water distributed over the area of the drainage basin.

The mean annual basin yields are reasonably consistent, averaging 0.041 $m^3/s/km^2$, equivalent to about 1300 mm of precipitation. Two obvious exceptions are the Mobile River and Northwest Brook systems, whose mean annual basin yields are, respectively, 30 percent and 42 percent above the average of the other five stations. This is likely due to much higher precipitation and lower evapotranspiration in these basins, which have substantial areas at higher elevations. As well, it is apparent that at all stations, the mean annual yield is a very large proportion of, or is indeed in excess of the mean precipitation at nearby precipitation recording stations. Again, it would appear that the precipitation data are not representative of major portions of these drainage basins.

Figure 4.2 shows the monthly distribution of runoff at several representative basins on the Avalon. Peak runoffs generally occurs in April and again in late fall. Low monthly flows are characteristically in the June, July, August period

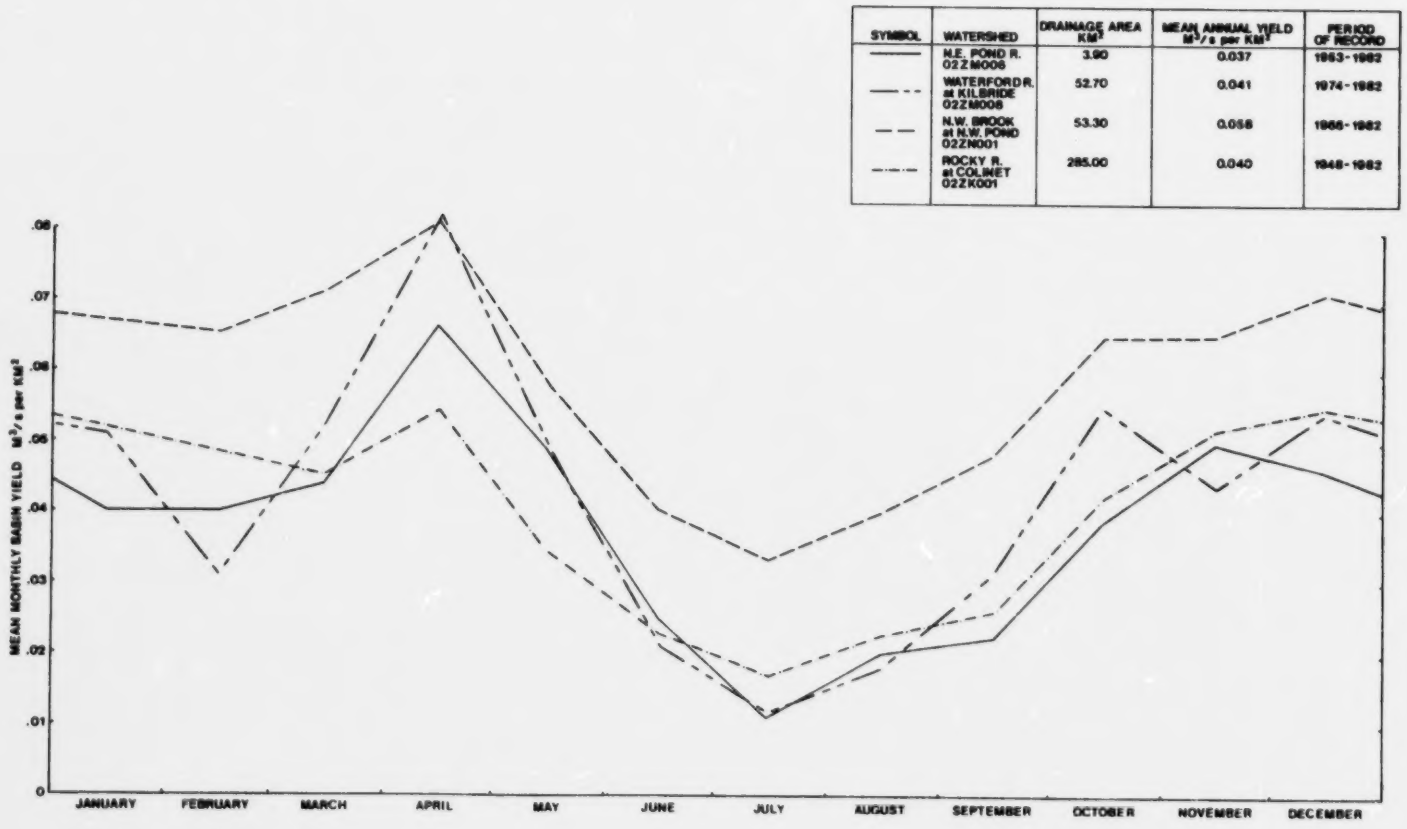


Figure 4.2 Mean monthly yields for representative basins, Avalon Peninsula.

and are in the range of 25-50 percent of mean annual flows.

4.2 Groundwater Discharge to Streams

The groundwater contribution to streamflow in a drainage basin each year is equivalent to the groundwater recharge in that basin, plus or minus any change in groundwater storage. In order to calculate this contribution, and thus groundwater recharge, a process of baseflow separation using the envelope curve technique was carried out. Representative stream discharge data for calendar years 1977 and 1981 from both Rocky River at Colinet and Waterford River at Kilbride were utilized. Figure 4.3 shows the 1981 daily stream discharge at the Waterford River station and the delineation of the groundwater discharge component of flow. The lower portion of the figure is the 1981 groundwater hydrograph from an overburden observation well near Torbay (Robinson, 1982).

There is a very strong correlation between the stream discharge hydrograph and the observation well hydrograph. Essentially every snow melt or rainfall event which creates a stormflow response also results in a period of groundwater recharge. The larger the event, the larger the streamflow and groundwater response.

The rapid response of the water table, both in recharge

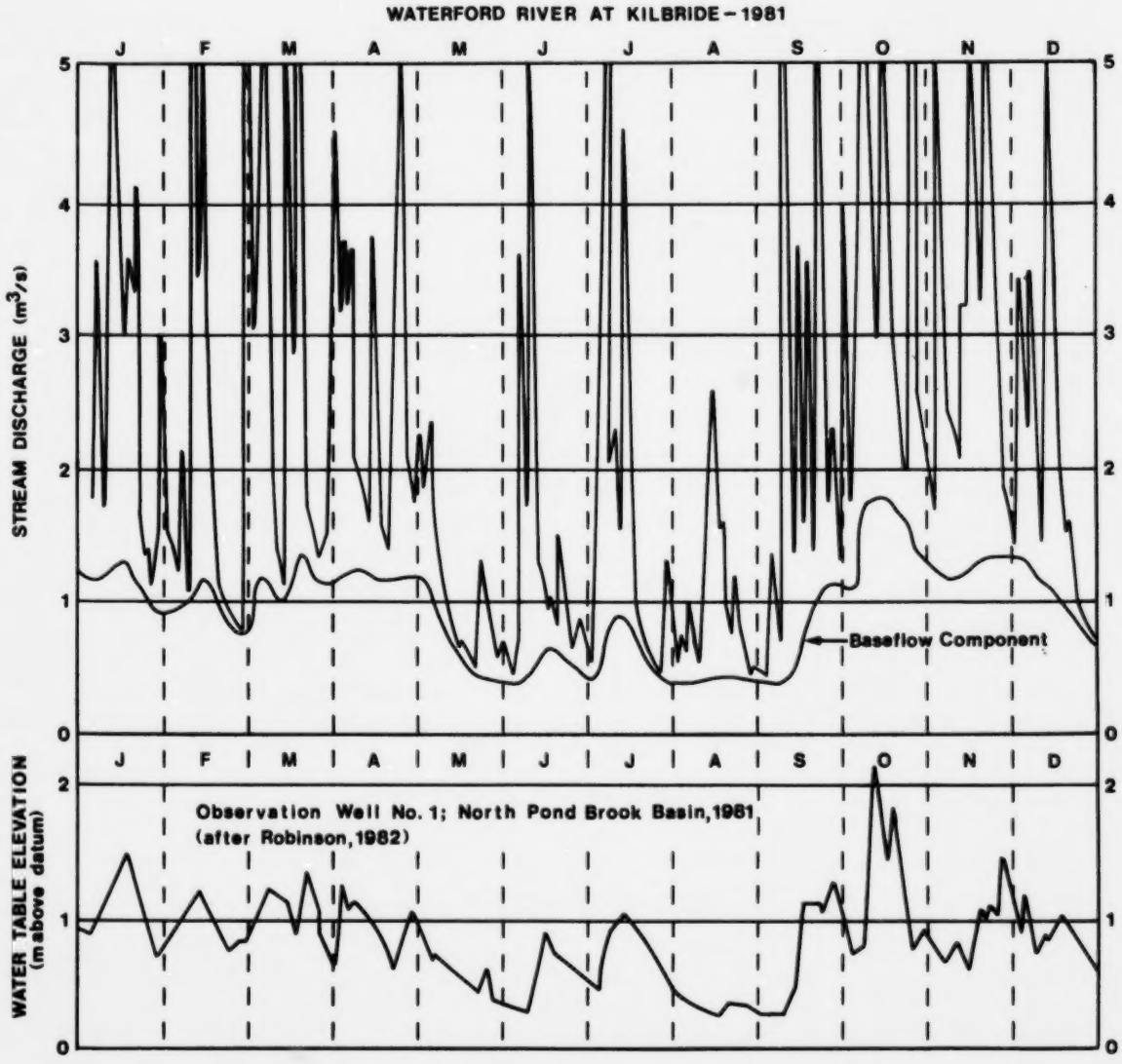

WATERFORD RIVER AT KILBRIDE - 1981
J F M A M J J A S O N D
STREAM DISCHARGE (m^3/s)
0 1 2 3 4 5
Baseflow Component
J F M A M J J A S O N D
WATER TABLE ELEVATION (m above datum)
0 1 2
Observation Well No. 1; North Pond Brook Basin, 1981
(after Robinson, 1982)

Figure 4.3 Daily stream discharge for 1981, Waterford River at Kilbride, showing separation of groundwater component of flow. Note the strong correlation with the water table fluctuations in an overburden dug well 15 km north, near Torbay (lower graph).

and decline, suggests relatively high soil moisture content conditions and moderate to high overburden permeability. The rapid water table declines and the relatively low magnitude of water level variations indicate that groundwater is readily discharged from storage to surface water bodies, maintaining baseflow. Thus the groundwater level fluctuation data provide a useful basis for the separation of the baseflow component of total flow. The apparent highly transient nature of water table levels and groundwater discharge can best be represented by the use of the envelope curve method (Figure 4.3). Figure 4.4 shows the hydrograph separation for 1981 stream discharge for Rocky River at Colinet station. The 1977 stream discharge data from each station were analysed in a similar fashion. The results, summarized in Table 4.2 show that in 1981, a year when precipitation was within 5 percent of normal at both St. John's and Colinet, baseflow comprised 34 percent and 32 percent of total stream discharge of the Waterford and Rocky Rivers, respectively. In 1977, when precipitation was 10-15 percent below normal, baseflow was 36 percent and 35 percent of total discharge, respectively.

An evaluation of groundwater recharge as a proportion of total precipitation in a drainage basin requires a reasonable estimate of total precipitation. As shown in Table 4.2, the 1981 total stream discharge values at both gauging stations

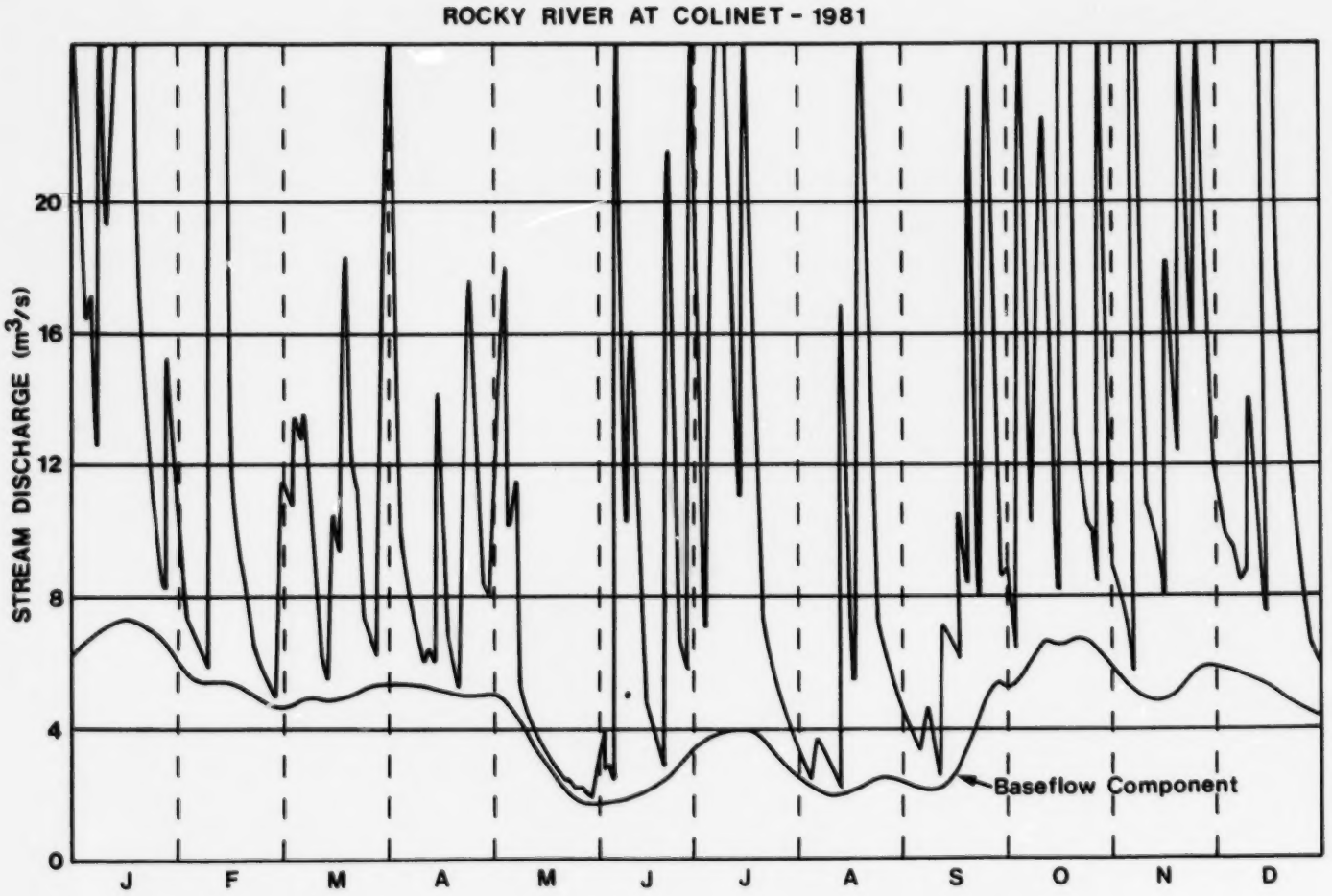


Figure 4.4 Daily stream discharge for 1981, Rocky River at Colinet, showing separation of ground water component of flow.

Table 4.2 Results of baseflow separation and evaluation of hydrologic budget parameters for Waterford River and Rocky River Basins for years 1977 and 1981.

Station	Year	Total Precip. (mm)	Total Stream Discharge (Q) (dm^3)	(mm*)	Baseflow (dm^3)	(mm*)
Waterford R. at Kilbride	1981	1573	7.89×10^4	1448	2.7×10^4	495
		$\frac{\text{Total Discharge}}{\text{Total Precip.}} = 92\%$		$\frac{\text{Baseflow}}{\text{Total Discharge}} = 34\%$		$\frac{\text{Baseflow}}{\text{Total Precip.}} = 31\%$
		Evapotranspiration = P-Q = 8% of Total Precipitation				
Rocky River at Colinet	1981	1393	4.07×10^5	1428	1.3×10^5	456
		$\frac{\text{Total Discharge}}{\text{Total Precip.}} = 103\%$		$\frac{\text{Baseflow}}{\text{Total Discharge}} = 32\%$		$\frac{\text{Baseflow}}{\text{Total Precip.}} = 32\%$
		Evapotranspiration = P-Q = ?				
Waterford R. at Kilbride	1977	1427	5.29×10^4	971	1.9×10^4	349
		$\frac{\text{Total Discharge}}{\text{Total Precip.}} = 68\%$		$\frac{\text{Baseflow}}{\text{Total Discharge}} = 36\%$		$\frac{\text{Baseflow}}{\text{Total Precip.}} = 24.5\%$
		Evapotranspiration = P-Q = 32% of Total Precipitation				
Rocky River at Colinet	1977	1197	2.61×10^5	916	9.2×10^4	323
		$\frac{\text{Total Discharge}}{\text{Total Precip.}} = 76.5\%$		$\frac{\text{Baseflow}}{\text{Total Discharge}} = 35\%$		$\frac{\text{Baseflow}}{\text{Total Precip.}} = 27\%$
		Evapotranspiration = P-Q = 23.5% of Total Precipitation				

* mm over basin

are an abnormally high fraction of total precipitation, indicating that the available precipitation values are lower than the actual average across the drainage basin. The values are more reasonable in the dry year 1977, but are probably still in error. Thus, while it is likely that groundwater recharge may be in the order of 20-25 percent in both basins, more complete precipitation data for each basin are required to make a precise evaluation.

It should be noted that in the Waterford Basin, the land area occupied by bog and lake areas is small and storage effects due to these surface water bodies are not considered significant. Such storage effects may be a factor in the Rocky River Basin and would cause an overestimation of the groundwater discharge component of stream flow.

It is likely that overburden aquifers interact to a much higher degree with surface water bodies than bedrock aquifers due to the generally higher permeability of the overburden materials. Estimates of groundwater recharge therefore refer to the overburden aquifers. The amount of direct recharge to bedrock aquifers or groundwater leakage to them from surficial deposits cannot be evaluated in this manner, but would require a detailed understanding of the hydraulic properties of surficial and bedrock aquifers, their flow systems and the interaction between them.

4.3 Evapotranspiration

An attempt to estimate evapotranspiration as the difference between total precipitation and total runoff is shown in Table 4.2. As previously stated, the lack of representative precipitation data precludes the calculation of dependable evapotranspiration values in this manner.

Potential evapotranspiration calculated for St. John's Airport has been given by Nolan, Davis and Associates (1982) (Table 1.3).

5. WATER QUALITY

5.1 Surface Water Quality

Surface water quality monitoring has been carried out on several river systems since 1966 including Northeast Brook, Seal Cove River, Mobile River, Broad Cove Brook, Spout Cove Brook and Northeast River. These data have been collected and were published in 1982 in the report "Water Quality Data - Newfoundland 1965-1980" by Inland Waters Directorate, Water Quality Branch and Newfoundland Department of Environment, Water Resources Division. The reader is referred to this report, available from Inland Waters Directorate (Atlantic), for detailed statistical results of water quality analyses on a wide range of chemical parameters and coliform bacteriology.

A review of the available data shows that the aqueous geochemistry of surface waters at all locations sampled is very similar. Typically, these waters are very low in total dissolved solids, less than 25 mg/L, pH values are generally between 4 and 6.5 and average alkalinity and hardness values are less than 10 mg/L. The low pH values and alkalinities suggest that these waters could be very susceptible to the effects of acidic precipitation. The major ion chemistry at all locations is indicative of surface runoff contact with or

groundwater baseflow through very low solubility geological materials. Surface water quality is quite comparable to the geochemistry of shallow groundwater in aquifers composed of relatively inert rock materials such as granites or siliceous sedimentary rocks.

The levels of nitrates, phosphorous and heavy metals and coliform bacteria are ubiquitously very low and dissolved oxygen values are generally greater than 9 mg/L indicating a relatively pristine water quality unaffected by natural contaminants, eutrophication, or human activities.

5.2 Groundwater Quality

Groundwater, whether in surficial deposits or in bedrock attains geochemical characteristics particular to the rock type or types through which it passes. The resulting geochemical signature is determined by (1) the order in which water encounters particular rock types, (2) the residence time in a particular rock type and (3) the solubility of the rock mineral constituents.

In the complex geological environment of the Avalon Peninsula, groundwater flow systems are generally poorly understood. Groundwater may move through several different geological units prior to withdrawal from a well or discharge

to a stream, complicating interpretation of aqueous geochemistry. On the other hand, groundwater quality may be determined in the unsaturated zone of surficial deposits, for example, prior to reaching the water table.

Nonetheless, it is valuable to assess available groundwater quality data with the intent of focusing on (1) relationships between rock type or hydrostratigraphic unit and aqueous geochemistry of the incumbent groundwater, (2) possible modes of genesis of the water chemistry and (3) evidence of water quality problems, natural or anthropogenic, which might affect the suitability of the water for various uses.

Groundwater quality data for the Avalon Peninsula area were obtained from the files of the Newfoundland Department of Environment and Department of Municipal Affairs. These included analyses in support of regional water quality surveys, investigations of water quality problems, samples collected during well yield tests and assessments of water quality in municipal supplies. Table 5.1 (in pocket) is a summary of the available information. The data represent water quality in sixty-one wells at 24 locations on the Avalon shown in Figure 5.1. There is a paucity of data from the western and southern coastal regions, as well as from the predominantly undeveloped central area.

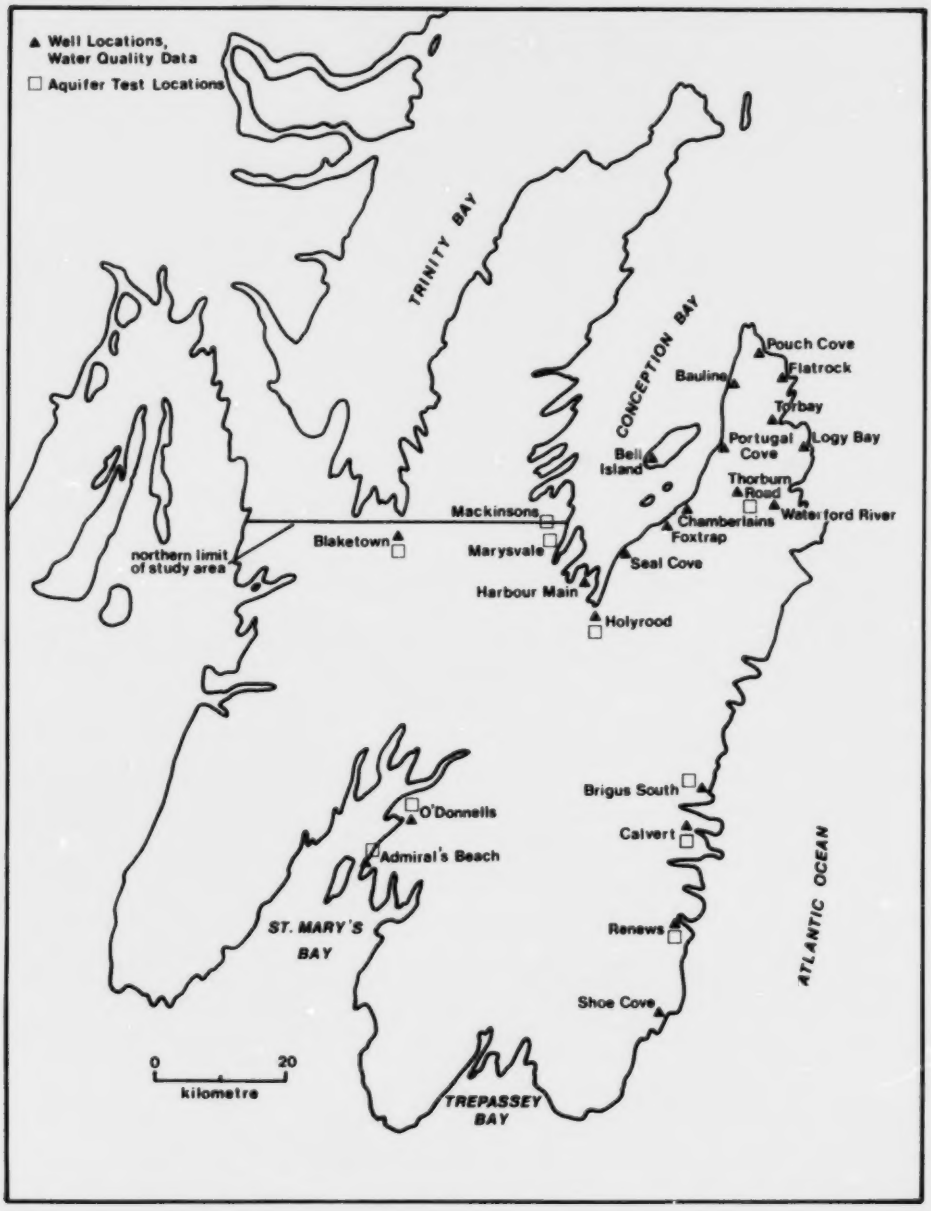


Figure 5.1 Location of wells sampled for water quality analysis and aquifer test locations.

Data on groundwater quality in the Avalon Peninsula have also been compiled in the Shawinigan-MacLaren (1968) report. Twenty eight analyses are presented from fourteen communities. However, the data are not sufficiently complete with only calcium, magnesium, alkalinity, sulfate and chloride plus nitrate actually being measured. No information regarding well type (dug or drilled) is provided. Overall water quality and suitability for consumption cannot be assessed from this information.

In the data presented in Table 5.1, major ion chemistry (Ca, Mg, Na, HCO_3, Cl, SO_4) has been fully analysed in about 70 percent of the samples. The majority of analyses were completed in the last 6-8 years at only two laboratories, so that the analytical methods are assumed to be fairly consistent. Mass charge balance errors, i.e.,

$$\text{Mass Charge Balance Error}\{\%\} = \frac{\sum \text{+ve ions(epm)} - \sum \text{-ve ions(epm)}}{\sum \text{+ve ions(epm)} + \sum \text{-ve ions(epm)}} \times 100$$

are generally less than 10 percent except in several cases where sodium analyses have not been carried out and sea water or road salt contamination has occurred. Other errors in mass charge balances indicate sampling or analytical error or ommission of important chemical species in the analysis.

Timing and methods of preservation and filtration of samples can have a large effect on the results of analyses such as pH, alkalinity, iron and manganese.

5.3 Overburden Groundwater Quality

As discussed in Chapter 3, dug wells are more common than drilled wells on the Avalon. However, data on dug wells are relatively sparse and few analyses of water samples collected from dug wells are available.

Nine dug wells completed in the surficial deposits in the Thorburn Road area (ablation moraine) and Torbay areas (stony till) have been sampled by the Department of the Environment. The results show that these groundwaters have low TDS (or specific conductance) values and pH values between 5 and 6. In the Thorburn Road area, the presence of high iron and manganese concentrations is indicative of the low pH and low redox potential environment which mobilizes these ions. This is common in areas where decomposition of soil organics consumes oxygen from infiltrating precipitation and increases concentrations of both carbonic acid and natural organic acids. The manganese and iron are often leached from the soil zone or overburden. The overburden in these areas apparently lacks soluble constituents such as calcite or dolomite, as evidenced by the low pH, alkalinity

and hardness. The high nitrate level (13.61 as N) at Torbay well NPB#4 is above the acceptable level for drinking water (Health and Welfare Canada, 1978) and suggests contamination from a source such as animal manure, septic waste or chemical fertilizer.

5.4 Bedrock Groundwater Quality

Water quality data was compiled from analyses of 42 bedrock wells in the Avalon Peninsula area. Several of the analyses suggest groundwater contamination by anthropogenic sources, or sea water, masking the "normal" geochemistry of the groundwater at these locations. In general, the bedrock groundwaters of the Avalon can, based on the available data, be assigned to three generic groups.

Group 1 - These are calcium bicarbonate type waters having appreciable hardness and alkalinity (>50 mg/L as $CaCO_3$) and pH values between 6.5 and 9. Fifty percent of the bedrock wells fall into this group. This water type generally results from the dissolution of calcite by carbonic acid from atmospheric precipitation and the soil zone:

$$CaCO_3 + H_2CO_3 \rightleftharpoons Ca^{+2} + 2HCO_3^-$$

The concentrations of hardness (due to calcium) and alkalinity (due to bicarbonate in this case) are directly proportional to the availability of carbonate minerals in the

overburden or in the bedrock of the flow system, up to the point of carbonate mineral saturation. Hardness and alkalinity, conventionally expressed as "mg/L $CaCO_3$", are usually about equal because of the 1:1 equivalent ratio of calcium and bicarbonate being produced. Waters which appear to be at or near saturation with respect to calcite occur in all ten Bell Island wells and one Torbay well. The two wells at Admiral's Beach indicate groundwater saturation with respect to dolomite. The data suggest that calcite may be present in the matrix of the Ordovician Bell Island and Wabana sedimentary units or in the overburden materials. Glacial material eroded from the early Cambrian Formations may be the source of dolomite saturation in Admiral's Beach wells.

Lower hardness, alkalinity and pH values are found in waters from Flatrock, Foxtrap, Harbour Main, Holyrood, Indian Pond, Pouch Cove, and possibly some Torbay wells. It is notable that even very small concentrations of calcite (<0.1 percent by weight) can significantly neutralize corrosive, low pH soil waters. In these areas, one can speculate that the carbonate minerals may occur as surface coatings on fracture planes or in the glacial tills.

Group II: These are sodium bicarbonate type waters generally having high pH (>8) and high alkalinity, and low hardness.

This water chemistry may result from aluminosilicate weathering processes as in the case of albite (Na - feldspar):

$$NaAlSi_3O_8(albite) + H_2CO_3 + H_2O \rightleftharpoons$$
$$Al_2Si_2O_5(OH)_4(Kaolinite) + Na^+ + HCO_3^- + H_4SiO_4$$

Although only wells at two locations, O'Donnells and Blaketown, appear to fit this description, some wells in Group 1 and other bedrock wells exhibit water chemistry which may be, in part, a result of Group 11 processes, the latter being masked by the higher solubility of the carbonate minerals. The Blaketown well is completed in the Quidi Vidi Group sandstone, known to contain fresh feldspar grains.

Group III : This is very soft, acidic (pH 4.0-5.5), low alkalinity water, with low total dissolved solids. The geochemical makeup and genesis of these waters are essentially the same as the overburden wells discussed previously. In fact, these bedrock wells probably obtain local recharge from such overburden deposits with very little subsequent alteration of water chemistry. These waters could thus be expected to be "young" groundwater. Two wells at Calvert, including one proposed municipal well 36.5 m deep, exhibit this type of water.

In summary, the available data suggest that groundwater

in bedrock aquifers of the Avalon Peninsula can generally be described by one of three modes of genesis. The three resulting water types generally indicate low solubility of the parent rock materials. Major ion chemistry usually involves some combination of calcium, magnesium, sodium and bicarbonate. Chloride and sulfate concentrations are normally very low, and probably result from airborne sea spray.

Histograms of all significant chemical species in both bedrock and overburden wells are shown in Figure 5.2. Although this representation of the geochemical data does not attempt to correlate geological units to geochemistry, it does provide a broad overview of the groundwater chemistry of the Avalon Peninsula area.

Almost 50 percent of water wells documented in Table 5.1 (in pocket) have one or more parameters whose values exceed acceptable limits (Health and Welfare Canada, 1978). Figure 5.3 shows the number of exceedances for each significant chemical species. The analyses of health-related parameters show no unacceptable levels of heavy metals (cadmium, copper, lead, zinc) or sulfate, and only one unacceptable nitrate value, that from a dug well at Torbay. Exceedances of most parameters on Figure 5.3 usually involve aesthetic or domestic water quality problems, sodium being a possible health hazard to persons on sodium-restricted diets.

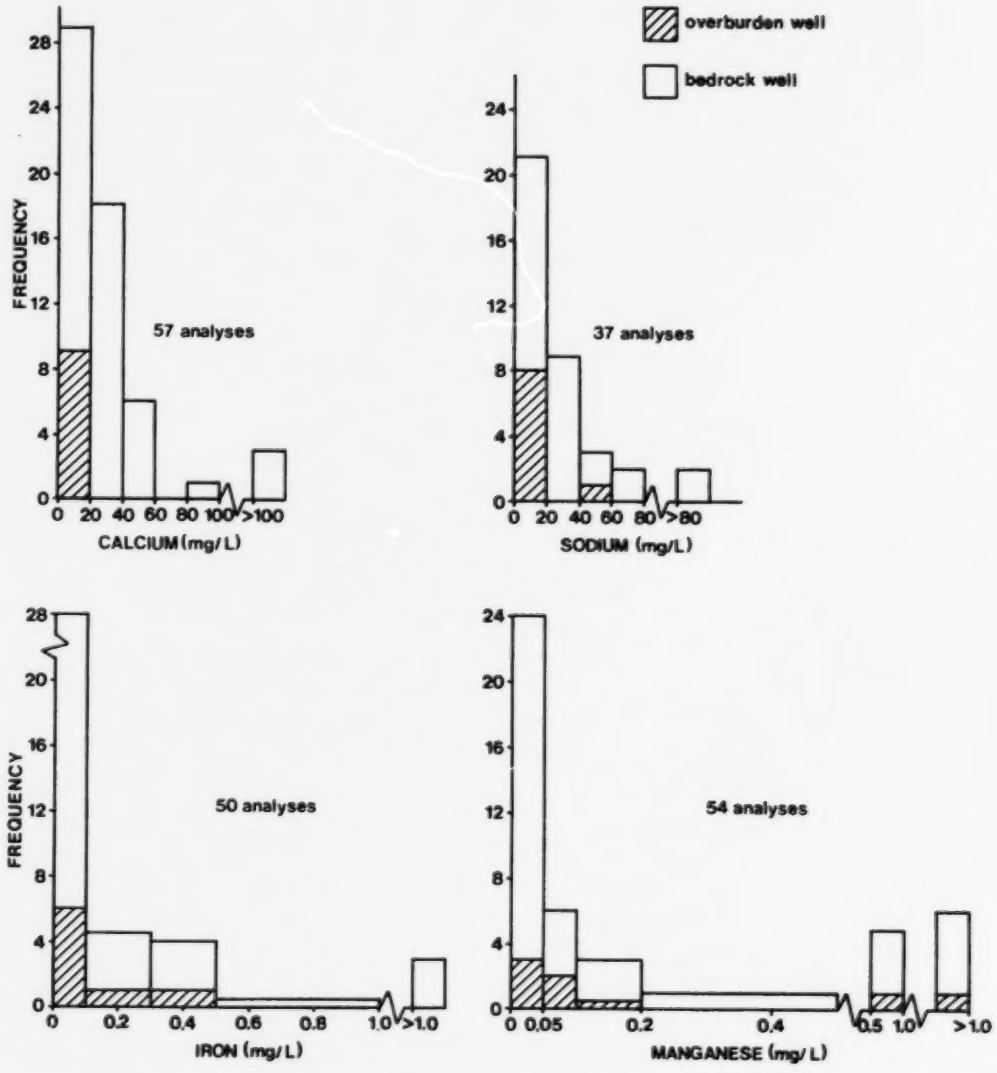


Figure 5.2 Histograms of significant chemical species in both bedrock and overburden wells.

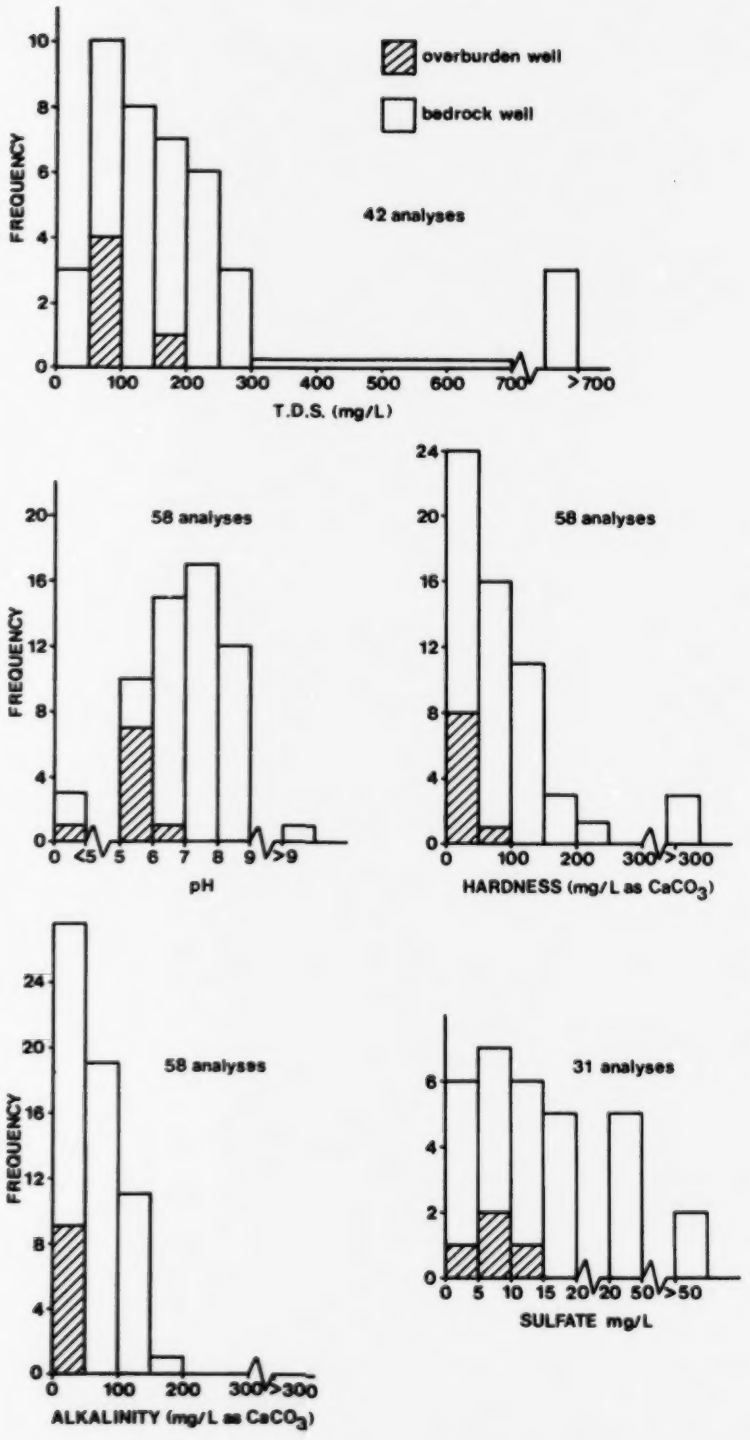
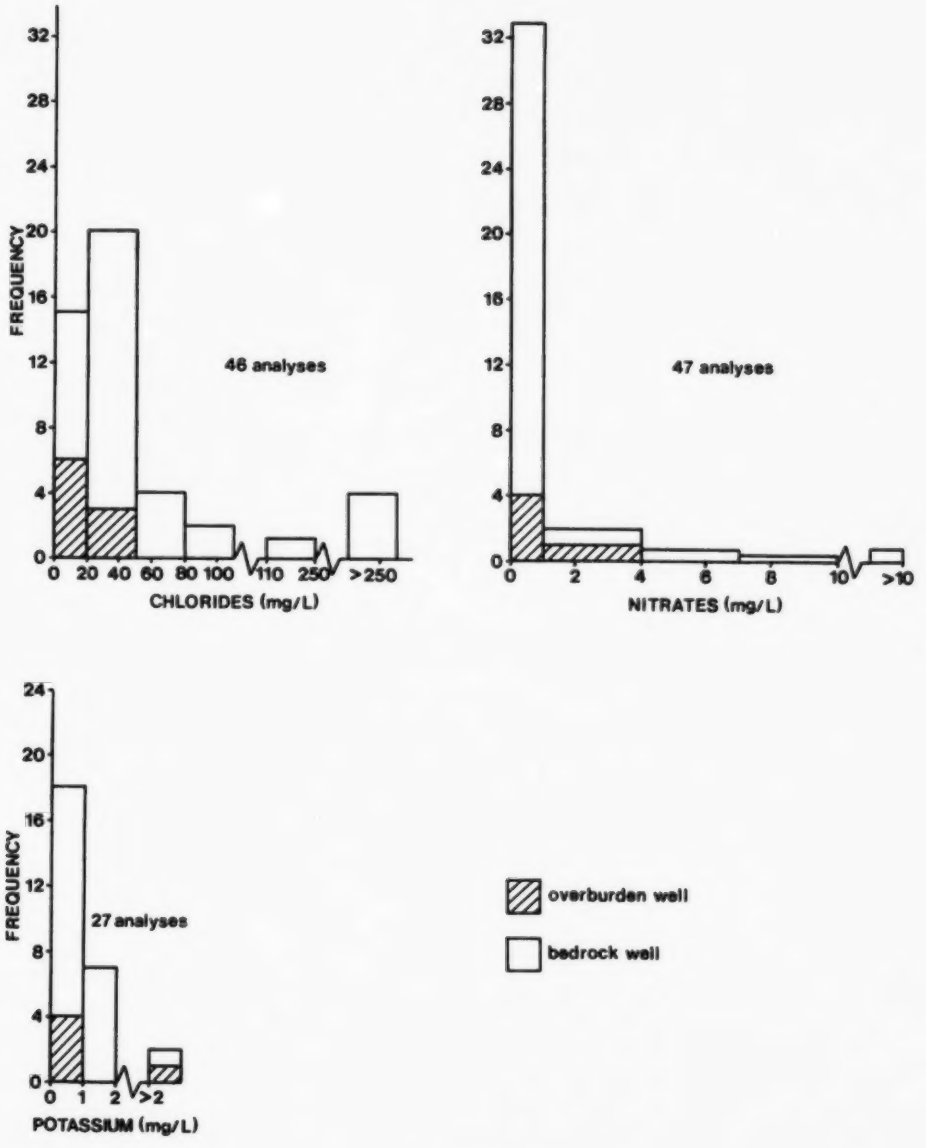


Figure 5.2 Continued.



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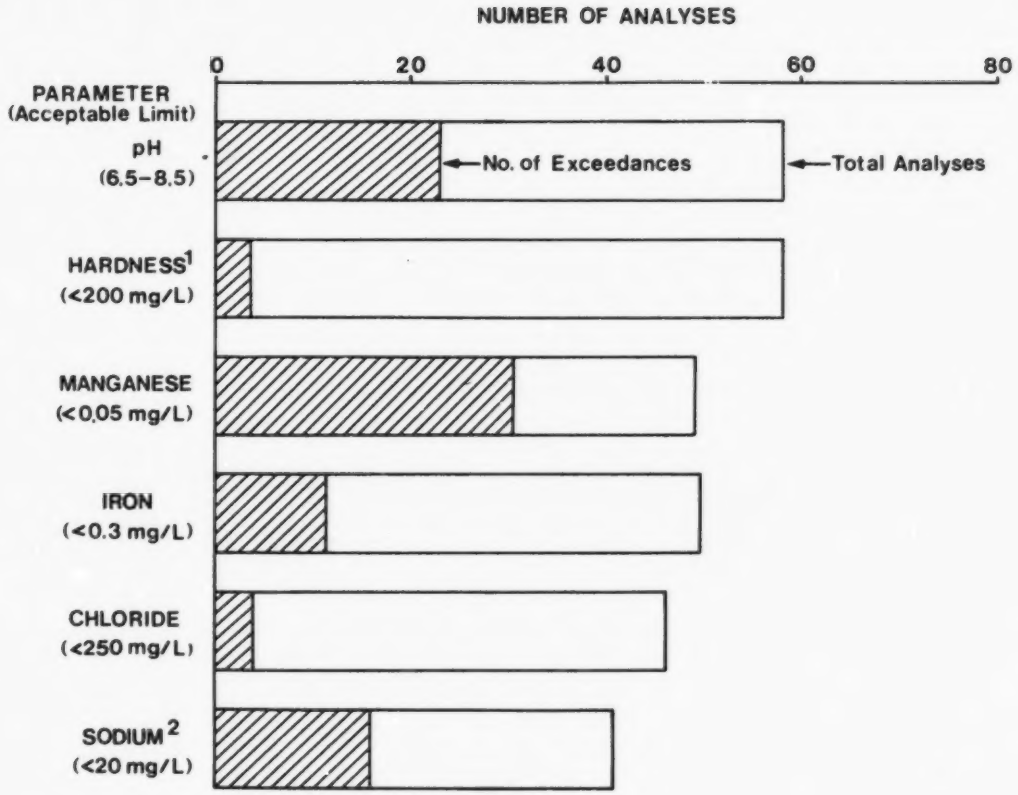

Note 1: Hardness values greater than 200 mg/L are considered poor quality from a domestic use standpoint.

Note 2: Persons on sodium-restricted diets should advise their doctor when sodium concentration in water

Figure 5.3. Graph showing number of unacceptable results of several parameters versus total number of available analyses.

The most common chemical water quality problem in wells of the Avalon peninsula is high manganese concentrations, often with associated high iron values. Unacceptable levels of either constituent causes staining of clothes and fixtures and fouling of pumps due to precipitation of iron and manganese oxy-hydroxides upon oxidation of these metal ions. In most cases the occurrence of iron and manganese in these wells is considered to be natural, although their solubility can be enhanced under conditions created by groundwater contamination. This may, in fact, be the case in some overburden wells in the Thorburn Road area, where manure lagoon overflow is suspected.

The exceptionally low and exceptionally high pH values recorded are also considered to be due to natural processes. The lower pH waters can cause corrosion problems and may require treatment for some industrial uses.

High chloride and sodium values in groundwater, often combined with higher than normal hardness, may result from one of a number of contaminant sources such as landfill leachate, road salt, sea water intrusion or septic waste. A number of wells at Pouch Cove, Bauline, St. Phillips, Chamberlains and Holyrood exhibit these characteristics and in these cases sea water intrusion is obviously suspected.

The Shawinigan-MacLaren Report (1968) suggests sea water or, less likely, road salt contamination of some wells at St. John's, Bell Island, Trepassey, Winterton and Bay Roberts.

6. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

The lack of usable data on dug wells, given their widespread use, is a major handicap to this study. The rough division of the surficial deposits in terms of moraine units and outwash deposits is an adequate first approximation for a regional study of this nature. However the hydraulic characteristics of the S2 Unit, the extensive outwash deposits along the heavily populated southeast side of Conception Bay, have not been properly assessed. The well drilling procedures in this area do not appear to have incorporated adequate well screening (or casing slotting) and well development practices. A systematic program of properly locating wells and compiling detailed data on well yields and well completion and development procedures would allow one to make a realistic assessment of the groundwater potential of this aquifer system as well as assess the nature of existing and potential contamination problems in this area.

Analysis of the well yield and well depth data has shown that with increasing well depth there is a decrease in well yield. No attempt has been made to correct well depths for casing length in order to compare the length of the open well interval (producing zone) to well yield or to express the data in terms of well yield per unit length of well. For the Harbour Main, Conception and St. John's Groups correcting for

casing lengths (Appendix B) will not significantly alter the well depth - well yield relationships. Despite the scatter in the data a sufficient number of wells were available for the Harbour Main, Conception and St. John's Groups as well as for the grouping of Random, Bonavista, Smith Point, Brigus, Chamberlains Brook, Manuels River and Elliot Cove Formations to ensure an adequate statistical description of the well depths and well yields for these lithologies. It is obvious from even a cursory analysis of the well depth - well yield data that many of the deeper wells are not justified as a source of domestic water supplies. Instead of drilling deeper wells the adequacy of existing well development procedures should be determined and a program of improving the yield of water wells by hydraulic stimulation (Williamson, 1982) should be undertaken. A practical education program on well development techniques could provide considerable financial savings to the consumer and a more economical utilization of the existing groundwater resources.

Further assessments of the groundwater potential of the bedrock units of the Avalon Peninsula should recognize that adequate data exist for several of the major rock units. Thus future efforts should be geared to developing data on rock units for which very little data currently exist. Provision of detailed geological maps, covering selected areas, to the drilling community will assist in identifying the rock type

in which a well has been drilled and hence improving the data base. Examples of such maps are given in Chapter 2.

Uncertainities in quantifing the precipitation component of the hydrologic budget make it difficult to assess the groundwater recharge and discharge in a given drainage basin as a proportion of total precipitation. Using the strong correlation between groundwater stage and stream discharge, it is estimated that groundwater contribution to streamflow may be in the order of 20-25 percent. Rapid rises of water levels in observation wells due to rainfall events are also followed by rapid decreases of water tables during periods of no rainfall, indicating the relative vulnerability of dug wells to periods of no rainfall.

Groundwater quality has been discussed extensively in Chapter 5 with three generic groups being identified - calcium bicarbonate, sodium bicarbonate and a very soft, acidic, low alkalinity water. About 50 percent of the chemical analyses of well water examined showed one or more parameters whose values exceed acceptable limits. The most common water quality problem in wells is high manganese concentrations, often with associated high iron values. The elevated chloride values in several areas are probably a result of sea water intrusion. Future water quality problems can be expected from landfill operations such as the landfill

or "dump" located in the upper part of the drainage basin system above Foxtrap. On a local level, increased urbanization and the continued use of water well and septic tank systems will place increasing stress on the groundwater system. On a larger scale, the low pH values and alkalinities of the surface waters suggest that these waters are susceptible to changes in the acid level of precipitation due to atmospheric pollution. The impact of these changes on the groundwater system has yet to be assessed. Given the low buffering capacity of the soils of the Avalon region such increases in "acid rain" can only result in the degradation of the water resources of the area. The impact of concentrated releases of industrial atmospheric wastes is clearly visible in the Long Harbour area. Howevever analysis of the fluoride content of water supplies from both surface and well sources found the concentrations to be well below permissible levels (Canadian Public Health Association, 1978).

It is recommended that a detailed study of the surface and groundwater system be undertaken in the immediate Long Harbour area to determine the impact of a concentrated atmospheric pollution source in areas with low buffering capacities. In addition, a detailed surface-groundwater study of the southeastern side of Conception Bay (from Holyrood to Manuels) would provide the basis for an effective water

resource management plan in an area in which the surficial materials may hold considerable groundwater potential and which is facing significant increases in population. Such local and detailed studies will permit more data collection as well as verification of existing data, and hence a more precise interpretation and understanding of the water resources, and potential and existing pollution problems in the area being studied.

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Appendix A: Census Data

A-1. Population Statistics of Avalon Peninsula Study Area (incorporated communities).

Community	Census year			
	1966	1971	1976	1981
Admiral's Beach	288	402*	370	362
Aquaforte	206	186	172*	200
Avondale	526	944	937*	890
Biscay Bay	76	87	88*	92
Branch	517*	516	452	462
Colinet	320	264	246*	318
Colliers	815	774	840*	819
Conception Bay South	...	8,212	9,743*	10,856
Conception Harbour	1,046	1,005	910*	917+
Daniel's Point	181	...	...	
Dunville	1,622*	1,742	1,909	1,817
Fermuse	401	503*	531*	584
Ferryland	723	716	780*	795
Flatrock	529	680	743*	808+
Fox Harbour	765*	685	627	538
Freshwater, P. Bay	1,310	1,562	1,426	1,276
Gaskiers-Pt. la Haye	270	300*	633*	505
Goulds	...	2,280	3,317*	4,242+
Harbour Main	617*	652	1,313*	...
Harbour Main-Chapel Cove-Lakeview	...	...	...	1,303
Hogan's Pond	...	191	110*	129
Holyrood	1,125*	1,282*	1,610*	1,789+
Jerseyside	953	1,061	1,027	641
Lawrence Pond	11	-*	11	46
Long Harbour-Mount Arlington Heights	355	376*	675*	660
Mount Carmel-Mitchell's Brook-St. Catherine's				
Mount Pearl	4,428	7,211	10,193	11,543
Paradise	...	1,697*	2,131*	2,861*
Petty Harbour-Maddox Cove	932	940*	930*	853
Placentia	1,847	2,211	2,209	2,204
Point Lance	164	133	135*	141
Port Kirwin	153*	159	140	164
Portugal Cove	1,082	1,411	1,527	2,361*
Portugal Cove South	350*	371	354	371
Pouch Cove	1,374	1,483*	1,543	1,522+
Renews-Cappahayden	507	497*	528*	578
Riverhead, St. Mary's	381	445*	426	431
St. Bride's	465	598	578*	599
St. John's	79,884*	88,102*	86,576*	83,770*
St. John's Area	16,849*	14,040*	19.047*	24,485*

Community	Census year			
	1966	1971	1976	1981
St. Joseph's,S.M.B.	282	305*	294	262
St. Mary's	562	445*	485	701
St. Philip's	515	573	807	1,365*
St. Shott's	218*	226	221	239
St. Thomas	521	155	461	448*
St. Vincent's-St. Stephen-Peter's River	797	838	850*	796
Torbay	1,532	2,090	2,908*	3,394*
Trepassey	670	1,443*	1,427	1,473
Wabana	7,884*	5,421	4,824	4,254
Wedgewood Park	3	417	1,236	1,226*
Whitbourne	884	1,235*	1,268	1,233

Notes: ... not shown separately (for details refer to Population of Incorporated Cities,Towns and Communities, Newfoundland and Labrador, 1951-1981, Nfld Statistics Agency).

* denotes change in boundaries due to annexation, incorporation or boundary reduction.

\+ denotes change in boundaries but with no change in population.

A-2. Population Statistics of Avalon Peninsula Study Area (unincorporated communities).

Community	Census Year			
	1966	1971	1976	1981
Admiral's Cove (inc. Island Cove)	...	121	109	99
Angel's Cove	60	46	41	46
Argentia	145	13	68	93
Bauline, C.B.	273	297	163	423
Bauline East(=Bauline)	61	74	73	80
Bay Bulls (inc. Bread & Cheese; The Keys)	1,032	1,011	1,104	1,081
Bear Cove (see Witless Bay)	45	...	...	...
Blaketown	344	399	537	617
Bread & Cheese (see Bay Bulls)	212	...	...	...
Brigus Junction	102	68	80	78
Brigus South (inc. Hilldale)	87	78	74	112
Burnt Cove	150	147	134	173
Calvert	473	470	436	482
Cape Broyle	640	677	711	698
Cape Pine	5	.	...	...
Cape Race	10	-	-	...
Cape St. Francis	30	...	...	...
Cape St. Mary's	3	1	10	...
Chapel Cove (now incorp. with Harbour Main)	354	608	307	296
Codner (= Middle Bight see Foxtrap)	...	...	...	...
Cuslett	114	124	107	87
Donovans	...	...	41	107
East Meadows	-	-	537	2,188
Forest Field	40	32	42	36
Foxtrap (inc. Codner, Foxtrap, Greeley, Peachtown, Kelligrews)	888	908	566	2,292
Freshwater, Bell Island (=Parsonville)	294	222	226	136
Gallows Cove (see Witless Bay)	43	-	-	...
Georgetown	275	305	332	315
Glenvilla Court		...	251	313
Goulds Road	84	155	190	118
Great Barrisway	61	47	35	21
Harricott (inc.Tickles)	80	77	71	27
Hilldale (see Brigus South)	87	...	...	...
Indian Pond (see Seal Cove)	79	87	99	129

Community	Census year			
	1966	1971	1976	1981
Island Cove (see Admiral's Cove)	...	...	...	...
John's Pond	12	-	-	...
La Manche	8		8	14
Lance Cove, Bell Island	394	105	274	205
Little Barrisway	13	16	14	22
Long Pond (see Marysvale)	...	...	...	
Lower Pond (see Witless Bay)	52	...	...	...
Mahers	1	1	19	...
Mall Bay	112	78	75	71
Markland	322	311	339	344
Marysvale (inc. Long Pond)	575	650	703	700
Middle Bight (see Codner)	...	...	...	...
Mobile	93	95	150	171
Mussell Pond (see O'Donnell's)	...	...	...	...
New Bridge	54	63	67	62
North Harbour, S.M.B.	137	146	150	151
O'Donnell's (inc. Mussell Pond)	297	268	275	280
Parsonville (see Freshwater, Bell Island)	...	...	...	
Patrick's Cove	150	170	162	155
Peachtown (see Foxtrap)	220	268	449	...
Placentia Junction	6	...	0	...
Point Verde	328	309	277	296
Roaches Line (=Roches Line)	134	150	135	147
St. Michael's	51	50	62	48
Seal Cove, C.B.	442	619	438	497
Second Pond	25	-	...	...
Ship Cove, P.B.	39	20	27	26
Ship Harbour, P.B.	264	255	252	265
Shoe Cove	176	240	306	374
Shores Cove	38	37	40	52
The Keys (see Bay Bulls)	40	...	...	
Tickles (see Harricott)	...	...	...	...
Topsail Pond	19	...	166	214
Tors Cove	332	325	364	355
Witless Bay (incl. Bear Cove Gallows Cove, Lower Pond)	729	754	888	907

Notes: ... not shown separately (included with another community or with the unorganized part of a census subdivision).

- nil.

Appendix B: Water well records.

This appendix contains eighteen pages of data on water well records. These data are arranged in alphabetical order by electoral district. Within each electoral district the individual communities are also arranged in alphabetical order. Taking Blaketown in the electoral district of Bellevue as an example we note from column 2 that a total of 12 wells is listed for this community. Column 3 shows that the wells range in depth from 18.9 to 94.5 metres, with an average depth of 57.7 metres. Column 4 shows that the well casings range from 3.7 to 18.9 metres in length, with an average length of 8.0 metres. No data exists for the casing length of one well (1 N.D.). Column 5: static water levels range from 2.6 to 6.1 metres below ground surface, with an average value of 4.0 metres. Nine wells have no data on the static water levels. Column 6: well yields range from 2.3 to 27.3 litres per minute, with an average value 13.2 litres per minute. Column 7: 8 wells were drilled for the Department of Municipal Affairs and Housing, (DMAH), 3 wells for communities (Com), and one domestic well (Do). Column 8 shows that an overburden thickness of 6.1 metres was recorded for one well and that no data were recorded for the 11 remaining wells. The last column gives the bedrock geology map units that underly this area, i.e. units 17 and/or 22.

Electoral District - Bellevue

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Argentia Access Road TCH	1	76.2	5.5	N.D.	N.D.	1 Com	N.D.	17/22
Blaketown	12	18.9-94.5 (57.7)	3.7-18.9 (8.0) 1 N.D.	2.6-6.1 (4.0) 9 N.D.	2.3-27.3 (13.2)	8 DMAH 3 Com 1 Do	6.1 11 N.D.	17/22
Markland	3	69.5-137.2 (94.3)	8.2-21.9 (15.1) 1 N.D.	12.8 2 N.D.	4.6-18.2 (11.4) 1 N.D.	2 Do 1 Pu	11.0 Sand & Gravel 2 N.D.	22
Whitbourne	25	9.1-79.2 (38.8)	3.0-24.4 (7.3) 3 N.D.	1.5-7.0 (4.3) 20 N.D.	6.8-68.3 (18.6) 12 N.D.	11 Com 2 Pu 12 Com	4.6-11.0 (7.9) 12 N.D. Gravel	22/17

Electoral District - Conception Bay South

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Chamberlains	44	12.2-121.9 (42.4) 1 N.D.	3.0-41.8 (10.5) 7 N.D.	N.D.	2.3-68.3 (22.3) 17 N.D.	41 Do 3 Com	3.7-41.8 (12.9) 36 N.D. Sand, Gravel Clay	(21)30/28/27/1a/6 (2)1a (14)1a/6 (7)30/27/28/
Donavans	9	15.2-121.9 (56.8) 1 N.D.	4.9-13.7 (6.8) 2 N.D.	2.4 8 N.D.	6.8-68.3 (31.1) 6 N.D.	4 Co 5 Do	4.3 8 N.D. Boulder & Clay	(8)8/6 (1)12/11/8/6
Foxtrap	82	13.7-154.5 (54.5)	2.7-24.4 (37.8) 35 N.D.	1.6-5.5 (3.8) 78 N.D.	1.1-364.0 (35 0) 27 N.D.	59 Do 6 DMAH 17 Com	0.9-23.8 (9.6) 52 N.D.	(8)30/28/27 (42)30/28/27/3a/6 (5)30/28
Horse Cove Line	24	13.2-137.2 (45.0) 1 N.D.	3.0-9.1 (4.9) 5 N.D.	N.D.	2.3-113.0 (29.5) 55 N.D.	24 Do	6.7 23 N.D.	1/6

Electoral District - Conception Bay South, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Kelligrews	118	4.6-131.1 (40.) 2 N.D.	1.5-33.5 (17.1) 35 N.D.	3.0-7.6 (5.8) 115 N.D.	3.41-364.0 (29.0) 67 N.D.	110 Do 3 Pu 5 Com	1.5-65.5 (15.0) 94 N.D.	(77)30/28/27 (11)30 (10)30/28 (20)overburden
Long Pond	42	13.7-112.8 (46.6) 3 N.D.	3.0-24.4 (7.6) 15 N.D.	0.0-5.4 (2.7) 40 N.D.	1.1-182 (26.3) 13 N.D.	41 Do 1 Pu	0.6-11.0 (5.4) 22 N.D.	(5)30/28 (4)3a/6 (5)28/27 (7)28/27/30 (18)30/28/27/3a/6 (2)28/27
Manuels	158	7.0-97.5 (33.1) 4 N.D.	3.0-38.1 (8.7) 40 N.D.	0.0-21.3 (5.0) 147 N.D.	3.4-136.5 (25.3) 67 N.D.	134 Do 18 Co 6 Pu	0.3-25.9 (7.4) 132 N.D.	(15)1a (15)30/28/27 (13)30/28 (90)30/28/27/3a/1a (10)27/28
Octagon Pond	8	21.6-91.4 (54.1)	3.7-6.1 (4.6) 4 N.D.	N.D.	6.8-91.0 (37.2) 5 N.D.	3 Do 5 Com	3.7-3.7 (3.7) 6 N.D.	(8)6/10
Paddy's Pond	4	38.1-91.4	4.3-11.0	N.D.	9.1-20.5 2 N.D.	4 Com	N.D.	(4)6
Paradise	63	9.8-152.4 (53.3) 1 N.D.	3.4-20.1 (6.6) 36 N.D.	N.D.	1.1-91.0 (13.2) 41 N.D.	59 Do 3 Com 1 Pu	0.6-6.1 (3.6) 53 N.D.	(63)6
Seal Cove	59	12.2-106.7 (41.3) 4 N.D.	5.5-30.5 (12.1) 20 N.D.	0.0-14.3 (4.4) 55 N.D.	2.3-336.7 (48.3) 25 N.D.	59 Do 2 Co	0.9-16.8 (8.5) Sand, Gravel Clay	(49)30/28/27/30 (4)3a (7)30/27/28

Electoral District - Conception Bay South, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
St. Thomas' Line	17	15.2-94.5 (46.5) 3 N.D.	2.1-25.9 (7.2)	N.D.	2.3-41.0 (16.4) 8 N.D.	1 Mu 2 Ind 14 Do	5.5-9.4 (6.8) 14 N.D.	1/6
Three Island Pond	8	15.2-91.4 (45.1) 5 N.D.	3.7-8.1 (5.2)	N.D.	6.8-13.7 (9.9)	1 Com 7 Do	N.D.	6/1a
Topsail	94	9.1-132.2 (47.4) 11 N.D.	0.9-41.5 (9.7) 27 N.D.	1.8-10.0 (6.0) 91 N.D.	1.1-136.5 (18.9) 23 N.D.	9 Com 8 Ind 2 Mu 75 Do	0.6-39.6 (7.5) 67 N.D. sand, gravel boulders.	(68)30/28/27/1a/6 (6)28/26/25 (17)6/1a (1)6, (1)1a (1)12/11/8/6
Upper Gullies	68	12.2-121.9 (40.2) 8 N.D.	2.4-46.3 (17.7) 20 N.D.	5.8-10.4 (8.1) 66 N.D.	2.3-82 (28.1) 20 N.D.	2 Com 6 Ind 1 Mu 59 Do	1.5-36.9 (20.9) 42 N.D. sand,granite boulders,gravel	(47)30/28/27 (9)28 (3)28/26

Electoral District - Ferryland

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/mln.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Aquaforte	1	N.D.	3.4	N.D.	0	1 Do	0.9 topsoil	6
Bay Bulls	21	25.9-94.5 (59.0)	1.8-7.9 (5.1) 5 N.D.	3.0-14.0 (8.5) 19 N.D.	2.3-109.2 (17.3) 9 N.D.	6 DMAH 3 Com 2 Mu 10 Do	2.4-10.1 (5.4) 18 N.D. gravel	13
Brigus South	6	10.7-67.1 (44.7)	3.0-8.8 (5.5) 1 N.D.	N.D.	2.3-91 (33.0)	5 DMAH 1 Do.	0.3 5 N.D. green till soft porous	12

Electoral District - Harbour Main - Bell Island, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Middle Arm	2	19.8 1 N.D.	3.7-6.1 (4.9)	N.D.	13.7-18.2 (15.9)	2 Do	0.6-3.7 (2.1) gravel, broken rock	1a/1b/1c/6
Roaches Line	3	42.7-107.3 (80.5)	6.1-8.5 (7.1)	N.D.	3.4-13.7 (7.2)	3 Do	N.D.	6
Salmonier Line	12	9.1-112.8 (47.6)	4.9-14.6 (8.3) 4 N.D.	9.8 11 N.D.	2.3-51.4 (19.9) 3 N.D.	4 Mu 8 Do	4.0-13.7 (8.1) 7 N.D. gravel,sand rocks	6/8/11/5/1b/1c
Silver Springs	1	4.6	12.5	N.D.	N.D.	1 Do	N.D.	N.D.
Woodfords	4	61.0-127.4 (101.2)	N.D.	4.3 3 N.D.	4.6-22.8 (12.1)	3 DMAH 1 Mu	7.6 3 N.D.	6/1c/3b

Electoral District - Kilbride

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Blackhead	3	13.7-18.3 (15.5)	8.8 2 N.D.	1.8 1 N.D.	9.1 2 N.D.	3 Do	4.3-7.3 (5.9) 1 N.D. gravel	19
Goulds	73	6.1-182.9 (54.8) 1 N.D.	1.8-18.3 (6.1) 19 N.D.	1.5-5.3 (3.0) 69 N.D.	2.3-182.0 (29.2) 43 N.D.	21 Co 2 Mu 2 Pu 48 Do	1.5-9.8 (4.8) 64 N.D. sand & gravel	(72)12/13/18 (1)18
Heavy Tree Road	8	24.4-112.8 (39.7)	3.7-5.8 (4.3)	N.D.	4.6-546. (127.4) 2 N.D.	7 DMAH 1 Co	N.D.	N.D.
Kilbride	15	12.2-71.6 (36.1)	3.0-13.7 (7.0) 4 N.D.	N.D.	6.8-36.4 (15.5) 10 N.D	2 Co 13 Do	3.0 14 N.D.	13/12

Electoral District - Kilbride, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Old Bay Bulls Rd.	1	27.4	3.4	N.D.	91.0	1 Do	N.D.	12/11/8
Ruby Line	2	42.7-76.2 (59.4)	5.2 1 N.D.	N.D.	N.D.	1 Do 1 Co	N.D.	12/11/8
Shea Heights	5	12.2-51.8 (25.9) 1 N.D.	2.1-5.2 (3.7) 2 N.D.	N.D.	1.1-68.3 (18.9)	4 Do 1 Mu	0.9-4.6 (2.3) gravel	19
St. John's (Holbrook Ave.)	1	24.4	N.D.	N.D.	N.D.	1 Do	N.D.	12/13

Electoral District - Mount Pearl

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Brookfield Rd.	3	21.3-80.8 (49.3)	2.7-7.9 (4.6)	1.8 2 N.D.	45.5 2 N.D.	1 Com 2 Do	N.D.	12/13
Mt. Carson Ave.	1	56.4	5.5	N.D.	N.D.	1 Do	N.D.	12/11
Mt. Pearl	16	11.6-91.4 (41.5)	4.6-5.5 (5.0)	N.D.	11.4-13.7 (12.5)	1 Ind 1 Mu 14 Do	1.5 brown topsoil	12/11
Topsail Road	8	20.4-109.1 (67.4)	2.7-7.0 (5.3) 1 N.D.	3.0 7 N.D.	4.6-13.7 (8.7) 2 N.D.	4 Com 1 Ind 3 Do	4.6-5.3 (4.9) 5 N.D. gravel	12/11/8/6

Electoral District - Mt. Scio

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Beachy Cove	4	27.4-68.6 (45.3)	1.5-6.7 (3.9)	N.D.	22.8	4 Do	N.D.	1a/6

Electoral District - Mt. Scio, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Bennett's Road	3	38.1-54.9 (46.5) 1 N.D.	3.7-4.0 (3.8) 1 N.D.	N.D.	1.1-2.3 (1.7) 1 N.D	3 Do	0.9-5.5 (3.1) gravel	1a/4/5/6
Broad Cove	1	42.7	N.D.	N.D.	N.D.	1 Do	7.6	1a
C.A Pippy Park	1	91.4	3.0	N.D.	N.D.	1 Do	N.D.	8/11
Cedar Drive	1	79.2	6.7	N.D.	13.7	1 Ind	N.D.	N.D.
Cherry Lane	2	39.6-51.8 (45.7)	12.8 1 N.D.	N.D.	N.D.	1 Ind 1 Do	N.D.	30/28
Circular Rd.	1	121.9	3.0	N.D.	N.D.	1 Do	N.D.	13/16
Cumberland Cres.	1	21.3	N.D.	N.D.	N.D.	1 Do	N.D.	8/6
Firdale Drive	1	17.1	3.4	N.D.	13.7	1 Do	N.D.	N.D.
Grooves Road	1	67.1	N.D.	N.D.	54.6	1 Do	N.D.	8/6
Halls Road	2	29.6-33.5 (31.5)	4.9-5.8 (5.3)	N.D.	13.7	2 Do	N.D.	N.D.
Hogan's Pond	4	15.8-33.5 (23.4)	3.7-7.3 (5.3)	N.D.	N.D.	4 Do	N.D.	6
McNiven Place	1	21.3	5.5	N.D.	4.6	1 Do	N.D.	N.D.
Mitchell Pond	2	30.5-57.9 (44.2)	2.4-3.0 (2.7)	3.0 1 N.D.	22.8 1 N.D.	2 Do	N.D.	6
Mount Scio	1	21.3	N.D.	N.D.	18.2	1 Do	N.D.	N.D.
Mount Scio Road	3	39.6-106.7 (60.5)	5.2 2 N.D.	N.D.	9.1-11.4 (9.9)	3 Do	7.6 2 N.D.	N.D.
Nagles Hill	1	70.0	4.6	N.D.	N.D.	1 Do	N.D.	8
Neary's Pond Rd.	1	15.2	3.7	N.D.	22.8	1 Do	N.D.	6
Old Broad Cove Rd.	23	19.8-121.9 (53.1) 1 N.D.	2.4-6.4 (4.5) 5 N.D.	N.D.	2.3-227.5 (26.0) 9 N.D.	23 Do	4.0-6.7 (5.9) 19 N.D. brown sand porous grey-br. gravel, brown gravel	6/1a

Electoral District - Mt. Scio, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Oliver's Pond	2	62.5-106.7 (84.6)	2.7-4.9 (3.8)	N.D.	2.3	2 Do	N.D.	6
Penetamguishene	4	39.6-91.4 (63.5) 1 N.D.	2.7-5.2 (4.3) 1 N.D.	N.D.	27.3	1 Com 3 Do	N.D.	6
Portugal Cove	6	9.1-111.3	3.0-4.9	N.D.	2.3-68.3	6 Do	3.0-15.2	1a/4/5/6
St. Phillips	27	13.7-140.2 (46.4) 3 N.D.	1.5-24.4 (5.9) 4 N.D.	N.D.	2.3-68.3 (23.4) 16 N.D.	4 Mu 1 Com 22 Do	2.1-23.8 (9.4) 24 N.D. gravel,brn sand & clay,porous	(20)6/1a (6)1a (1)6
Thorburn Rd.	10	15.2-71.6 (44.2) 1 N.D.	2.1-5.8 (4.3) 1 N.D.	N.D.	4.6-22.8 (13.7) 4 N.D.	1 Com 9 Do	1.2 9 N.D. broken rock	12/11/8/6/1a
Tolt Road	5	9.1-100.6 (35.3)	4.6-9.8 (6.8) 2 N.D.	N.D.	13.7 4 N.D.	1 Com 4 Do	N.D.	1a/6
Tucker's Hill	3	33.5-68.6 (51.8)	2.7-23.2 (10.2)	N.D.	20.5-54.6 (37.5)	1 Com 2 Do	N.D.	1a/6

Electoral District - Placentia

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Argentia Access Rd.	2	10.4-16.5 (13.7)	10.4-11.3 (10.8)	N.D.	N.D.	1 Mu	N.D.	N.D.
Dunville	1	N.D.	N.D.	N.D.	N.D.	1 Do	N.D.	16/22/17/23/BAa
Fox Harbour	2	15.8-44.2 (30.0)	16.5-18.6 (17.5)	N.D.	9.1 1 N.D.	2 Do	17.0 1 N.D. boulders	BAa
Freshwater	1	45.7	6.4	N.D.	N.D.	1 Do	N.D.	BAa

Electoral District - Placentia, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Long Harbour	6	45.7-106.7 (75.1) 2 N.D.	4.0-8.8 (6.3) 2 N.D.	N.D.	2.3-18.2 (6.6)	4 Mu 1 Ind 1 Do	4.9-12.8 (9.0) 2 N.D. gravel	16/17
Placentia	1	64.0	N.D.	N.D.	N.D.	1 Do	N.D.	BAa/16
Point Verde	2	39.6-61.0 (50.3)	2.7-9.1 (5.9)	20.7 1 N.D.	4.6-91.0 (47.8)	2 Do	2.7-6.1 (4.4) brown clay, rocks	BAa

Electoral District - Port de Grave

Community	No of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Georges Town	1	N.D.	13.7	N.D.	159.3	1 Do	13.7	6
Hodgewater Line	1	70.1	12.8	N.D.	N.D.	1 Do	N.D.	16
Roaches Line	6	13.1-108.2 (47.1)	15.2-18.3 (16.7) 4 N.D.	N.D.	41.0 5 N.D.	1 Com 5 Do	3.7-8.2 (5.3) 2 N.D.	6
Waterbury	1	36.6	6.7	N.D.	N.D.	1 Do	N.D.	N.D.

Electoral District - St. John's Centre

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Patrick St.	1	36.6	11.6	N.D.	13.7	1 Do	N.D.	13
Scotts St.	1	27.4	N.D.	N.D.	N.D.	1 Do	N.D.	12/13

Electoral District - St. John's East

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver (m)	Geology Map Units
Quidi Vidi	2	30.5-91.4	5.2-10.4	N.D.	45.5	2 Do	N.D.	18/17/16

Electoral District - St. John's East Extern

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/ in.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Airport Road	5	9.8-47.5 (28.3)	N.D.	N.D.	4.6-54.6 (17.3)	4 Do 1 Ind	5.4-7.9 (7.1)	6
Bauline,Bauline L.	37	12.2-115.8 (44.0) 2 N.D.	1.8-11.3 (4.9) 8 N.D.	N.D.	2.3-68.3 (15.5) 14 N.D.	35 Do 2 Ind	1.5-10.1 (2.5) 33 N.D.	(16)1a/1b/1c/4/5/6 (10)1a/1b/1c (7)1b/1c (4)1a/1c
Blair Park	1	38.1	1.5	N.D.	13.7	1 Do	1.5 gravel, broken rock	6
Chimo Place	1	21.3	N.D.	N.D.	N.D.	1 Do	N.D.	12/11/13
Flatrock	20	10.4-122.0 (59.0)	2.5-9.8 (4.5) 7 N.D.	4.3 19 N.D.	6.8-100.1 (27.5) 10 N.D.	20 Do	0.9-4.3 (2.6) 18 N.D. green sandst.	6/5/4
Harbour View Ave.	2	70.1-90.0 (80.1)	81.0 (44.5)	N.D.	4.6 1 N.D.	2 Do	N.D.	N.D.
Indian Meal Line	10	24.4-85.3 (59.1)	2.1-6.4 (4.3) 6 N.D.	1.4-7.1 (4.3) 8 N.D.	4.6-27.3 (14.2) 2 N.D.	10 Do	2.4-6.7 (4.6) 5 N.D.	6
Logy Bay	16	15.2-108.2 (42.5) 2 N.D.	3.0-18.9 (7.2) 2 N.D.	N.D.	6.8-54.6 (17.9) 9 N.D.	1 Ind 15 Do	0.6-4.6 (2.6) 14 N.D. gravel	(14)12,13,16,17,18 (2)13/14

Electoral District - St. John's East Extern, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/ in.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Logy Bay Road	9	28.7-106.7 (66.5)	2.3-6.7 (4.8) 4 N.D.	N.D.	2.3-22.8 (9.1) 1 N.D.	5 Do 4 Ind	4.3-8.2 (6.3) 5 N.D.	12/13/16/17/18/19
Logy Bay Road Area (Sugar Loaf Road)	3	15.2-47.2 (31.2)	6.7 2 N.D.	N.D. N.D.	11.4 2 N.D.	3 Do	4.6 2 N.D. gravel	18/17/19/16/17/18
Major's Path	3	17.0-26.5 (21.7) 1 N.D.	4.6-6.0 (5.3) 1 N.D.	N.D.	22.8-41.0 (31.9) 1 N.D.	1 Do 2 Ind	3.4-4.3 (3.9) 1 N.D.	6
Malka Drive	1	42.7	N.D.		4.6	1 Do	140.9	N.D.
Marine Drive	5	47.2-99.1 (68.0)	3.1-10.4 (5.4)	N.D.	9.1-20.5 (14.2)	5 Do	N.D.	(2)17/18 (3)6/8/11/12/13/14/15
Middle Cove	10	25.8-106.7 (55.3)	1.8-7.6 (4.9) 1 N.D.	N.D.	2.3-45.5 (20.0) 6 N.D.	10 Do	N.D.	N.D.
Montrope St.	1	21.3	N.D.	N.D.	N.D.	1 Do	N.D.	12/11/13
Outer Cove	23	15.5-141.7 (42.4) 2 N.D.	3.1-22.3 (8.6) 10 N.D	N.D.	2.3-36.4 (22.8) 13 N.D.	23 Do	20.7 22 N.D. gravel	N.D.
Pine Line	7	21.4-70.0 (35.5)	5.1-7.3 (6.1) 2 N.D.	N.D.	9.1-22.5 (18.2) 4 N.D.	7 Do	7.0 5 N.D.	(4)6/8/11/12 (3)6
Portugal Cove	56	6.1-157. (61.0)	2.2-15.2 (4.7) 12 N.D.	0-19.8 (6.8) 51 N.D.	2.3-91.0 (16.0) 28 N.D.	53 Do 1 Ind 2 DMAH	0.5-9.1 (3.9) 47 N.D. gravel	N.D.
Portugal Cove Road	22	13.7-94.5 (50.7)	1.8-6.7 (4.6) 2 N.D.	N.D.	9.1-81.9 (21.1) 7 N.D.	1 Mu 1 Ind 2 Com 18 Do	5.8 21 N.D.	(19)6/1a/8 (3)6

Electoral District - Ferryland, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/mln.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Burnt Cove	2	82.3-89.9	N.D.	N.D.	N.D.	2 Ind	N.D.	13
Calvert	3	33.5-53.3 (44.7)	N.D.	N.D.	4.6-182 (70.5)	3 Ind	N.D.	6/8/11/12
Cape Broyle	4	20.1-62.5 (45.8) 1 N.D.	6.7-20.1 (12.6)	N.D.	2.3-136.5 (72.8)	2 DMAH 2 Do	9.1 3 N.D. sand	6/8
Cappahayden	2	64.6-66.4 (65.5)	N.D.	1.8	N.D.	2 Mu	7.0-7.6	13/12/16
Fermeuse	3	19.8-53.3 (36.6) 1 N.D.	8.2-10.7 (9.3)	N.D.	18.2 2 N.D.	3 Com	7.3 2 N.D. gravel	8
Ferryland	4	61.0-91.4 (75.8)	4.6-8.2 (6.7) 1 N.D.	N.D.	4.6-13.7 (7.6) 1 N.D.	2 Mu 2 Ind	3.0 3 N.D. brown clay & sand	12/13
Goulds	5	16.5-70.0 (31.9)	5.8-6.7 (6.2) 2 N.D.	N.D.	4.6-11.4 (8.0)	5 Do	5.8 3 N.D. brown & grey sand, gravel & clay	12/13
Mobile	6	15.2-33.5 (24.3) 2 N.D.	3.7-9.4 (6.6) 1 N.D.	9.4 5 N.D.	11.4-227.5 (75.5)	1 Ind 1 Mu 4 Do	3.7-7.9 (5.8) 4 N.D. gravel	13
Renews	11	19.8-68.3 (53.3) 3 N.D.	7.0-13.4 (10.6) 5 N.D.	2.7-11.6 (7.1) 8 N.D.	2.3-182 (53.5) 5 N.D.	6 Mu 1 DMAH	4.6-13.4 (8.3) sand,gravel	12,11

Electoral District - Ferryland, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/mln.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
St. Michael's	2	N.D.	16.5-38.1 (27.3)	N.D.	2.3 1 N.D.	2 Do	15.2-38.1 (26.7) sand,gravel & pug	13
Tors Cove	14	13./-182.9 (67.8) 1 N.D.	6.7-19.2 (15.1) 7 N.D.	N.D.	1.1-136.5 (26.2) 7 N.D.	5 Ind 3 DMAH 2 Com 4 Do	12.5 13 N.D. gravel	13
Witless Bay	13	13.0-94.5 (54.2) 3 N.D.	5.5-14.9 (8.5) 3 N.D.	4.9 12 N.D.	2.3-22.8 (11.1) 4 N.D.	3 Mu 1 Com 9 Do	4.9-6.1 (5.6) 9 N.D. gravel,boulders & sand.	16/13/12

Electoral District - Harbour Main - Bell Island

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Avondale	19	10.7-61.0 (31.0) 6 N.D.	2.1-8.5 (4.3) 6 N.D.	0.4-1.5 (1.0) 17 N.D.	1.1-91 (34.5) 6 N.D.	1 Mu 18 Do	0.3-8.8 (2.6) 11 N.D. gravel,bog	1c/1b
Bacon Cove	1	37.8	3.7	N.D.	11.4	1 Do	N.D.	6/1b/1c/5/27
Bell Island	30	15.2-201.1 (61.3)	2.4-10.7 (5.3) 8 N.D.	33.2 29 N.D.	6.8-273 (73.5) 16 N.D.	10 Mu 1 DMAH 1 Ind 18 Do	N.D.	33/32
Brigus Jct.Pk.Road	1	73.1	9.8	N.D.	15.9	1 Do	8.8 green,brown topsoil,till	1a/6

Electoral District - Harbour Main - Bell Island, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Chapel Cove	7	18.0-70.1 (40.2) 2 N.D.	2.7-112.8 (7.9)	2.4 6 N.D.	2.3-9.1 (5.5) 2 N.D.	7 Do	1.2-12.2 (8.3) sand & gravel	1a/6/27
Colliers	19	12.2-121.9 (46.4) 4 N.D.	1.8-13.4 (5.8) 1 N.D.	N.D.	1.1-91 (26.0) 3 N.D.	2 Com 1 Mu 16 Do	0.6-12.2 (6.8) 15 N.D. gravel,topsoil	1c/1b/1a/27
Conception Hr.	9	5.2-115.8 (45.1)	6.4-27.1 (12.4) 3 N.D.	N.D.	4.6-27.3 (13.1) 5 N.D.	1 Com 8 Do	5.2 8 N.D. gravel & large boulders	1b/1c/1a
Harbour Main	41	13.7-106.7 (41.8) 8 N.D.	2.1-13.4 (6.1) 9 N.D.	2.4-18.2 (8.5) 37 N.D.	0.6-182 (16.9) 13 N.D.	3 Mu 4 Com 34 Do	0.6-13.7 (3.6) 17 N.D. topsoil,fill gravel,pug	(1)1a/25/6 (4)6/5 (27)6/5/1a/1b/1c (7)6 (2)5
Healy's Cove	1	32.0	5.5	N.D.	N.D.	1 Do	N.D.	6/1c
Hodge Water Line	5	15.2-103.6 (65.5)	6.7-13.4 (10.1)	N.D.	6.8-273 (62.8)	5 Do	3.0-12.2 (7.6) 3 N.D.	16
Holyrood	58	9.4-108.2 (44.3) 9 N.D.	1.8-21.6 (8.4) 17 N.D.	0-8.5 (5.3) 57 N.D.	2.3-455 (71.6) 23 N.D.	16 Com 4 Mu 1 Ind 2 DMAH 38 Do	0.6-90.5 (13.3) 43 N.D. gravel,sand bog, topsoil boulders	(19)6,1a,1b,1c,3a (8)6/1a/1b/1c/3b (20)6 (2)1a (8)1c (1)1a/1c
Holyrood Junction	1	13.7	N.D.	N.D.	11.3	1 Do	13.7	N.D.
Marysvale	4	109.7-121.9 (117.9) 1 N.D.	6.7-13.4 (10.3)	N.D.	1.1-9.1 (4.3)	1 Do 3 Mu	10.4 3 N.D. gravel	6/27/1a

Electoral District - St. John's East Extern, continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/ in.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Pouch Cove	40	9.1-122. (50.0) 1 N.D.	2.4-11.0 (6.2) 7 N.D.	N.D.	2.3-79.6 (19.0) 17 N.D.	1 Mu 1 DMAH 38 Do	2.7 39 N.D. gravel	6
Radio Range Rd.	2	32.0-38.1 (35.1)	7.3-7.6 (7.5)	N.D.	9.1-45.5 (27.3)	2 Do	6.1 sand,gravel, broken rock	6
Robin Hood Bay Rd.	3	21.3-76.3 (51.8)	2.7-6.7 (4.5)	N.D.	9.1 2 N.D.	1 Do 2 Com	N.D.	12/13/16/17/18
Savannah Park	2	70.1 1 N.D.	2.7 1 N.D.	N.D.	4.6 1 N.D.	2 Do	0.9-6.1 (3.5) sand,gravel broken rock	6
Shoe Cove	19	12.2-45.7 (18.9)	2.4-11.3 (6.4)	N.D.	13.7-68.3 (38.9)	19 Do	N.D.	6/4/5
Sugar Loaf Rd.	6	15.2-97.4 (41.5) 1 N.D.	4.3-6.7 (5.4) 3 N.D.	N.D.	6.8-11.4 (7.6) 3 N.D.	2 Com 4 Do	4.6 5 N.D. gravel	13/16/17/18
T.C.A. Road	1	91.4	4.9	N.D.	N.D.	1 Do	N.D.	N.D.
Torbay	83	12.2-146.3 (53.2) 7 N.D.	1.8-17.4 (7.7) 31 N.D.	N.D.	2.3-54.6 (13.2) 42 N.D.	1 Ind 2 DMAH 3 Com 4 Mu 73 Do	0.9-12.2 (5.2) 71 N.D. gravel	(61)6/4 (22)6
Torbay Road	7	21.0-91.4 (51.8)	3.0-6.1 (4.8) 2 N.D.	N.D.	25.0 6 N.D.	2 Com 1 Ind 4 Do	N.D.	(5)6/8/11/12 (2)6
Wedgewood Park	2	70.0-76.2 (68.6)	20.7-23.8 (22.3)	N.D.	N.D.	2 Do	N.D.	6
Windsor Heights	7	25.9-91.4 (52.0)	4.6-5.8 (5.1) 2 N.D.	N.D.	2.3-27.3 (12.9) 1 N.D.	7 Do	6.1-6.4 (6.2) 5 N.D.	6

Electoral District - St. John's North

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Bauline Line	1	40.0	6.7	N.D.	N.D.	1 Do	3.6 gravel	6/5/4/1a
Beachy Cove	2	38.1-48.8 (43.4)	6.7-18.6 (12.6)	N.D.	9.1-18.2 (13.7)	2 Do	3.7 gravel	1a/6
Bennetts Road	3	27.4-51.8 (39.6)	N.D.	N.D.	N.D.	1 Com 2 Do	N.D.	1a/4/5/6/6/1a
Dundas St.	1	89.9	N.D.	N.D.	N.D.	1 Do	N.D.	12/11
Old Broad Cove Rd.	2	30.5-67.1 (48.8)	4.6 1 N.D.	N.D.	13.7	2 Do		6/1a
Portugal Cove	32	15.2-99.1 (52.8) 10 N.D.	2.4-7.9 (4.5) 20 N.D.	4.6 31 N.D.	1.1-54.6 (16.7) 20 N.D.	4 Com 28 Do	0-5.5 (2.8) 23 N.D.	1a/4/5/6
Portugal Cove Rd.	2	45.7-73.2 (59.4)	N.D.	N.D.	N.D.	2 Do	N.D.	6/1a/8
Prince Philip Pkwy.	1	44.2	N.D.	N.D.	N.D.	1 Do	N.D.	12
Torbay Road	1	59.7	N.D.	3.5	468.7	1 Ind	4.6 glacial till, high % frac. granite bdrock material	6/8/11/12
Whiteway St.	1	30.5	N.D.	N.D.	N.D.	1 Do	N.D.	12

Electoral District - St. John's South

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Bradbury	1	30.5	N.D.	N.D.	N.D.	1 Do	N.D.	13

Electoral District - St. John's West

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
South Ave.	1	57.9	N.D.	N.D.	N.D.	1 Do	N.D.	13/12

Electoral District - St. Mary's-The Cape

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Admiral's Beach	4	32.3-76.1 (54.4)	4.3-7.0 (5.7)	N.D.	11.4-113.8 (67.4)	4 Mu	2.5-4.8 (3.5) gravel	6
Bramen	2	10.1-29.0 (19.5)	7.0-10.1 (8.5)	1.8-4.3 (3.0)	13.7-136.5 (75.1)	2 Ind	10.1 sand,beach rocks 1 N.D.	26
Colinet	1	33.5	6.1	N.D.	15.9	1 Do	N.D.	22/17/16
Cuslett	1	27.4	13.7	7.6	18.2	1 Ind	N.D.	27/23/4
Harricott	1	N.D.	19.5	N.D.	91.0	1 Do	19.5 sand,small stones	6
Mount Carmel	3	30.5 2 N.D.	3.4-15.2 (8.4)	N.D.	4.55-9.1 (6.8) 1 N.D	2 Do 1 Mu	6.1-12.2 (9.2) 1 N.D gravel	6
Mt.Carmel/Salmonier	4	15.2-56.1 (41.2)	4.9-21.6 (13.3)	2.4 3 N.D.	9.1-27.3 (15.2) 1 N.D.	4 Do	21.3 3 N.D. gravel,small boulders	6
O'Donnells	2	80.6 1 N.D.	17.4-18.3 (17.8)	N.D.	2.3-27.3 (14.8)	2 Mu	15.2 1 N.D. sand,gravel	6

Electoral District - St. Mary's-The Cape continued

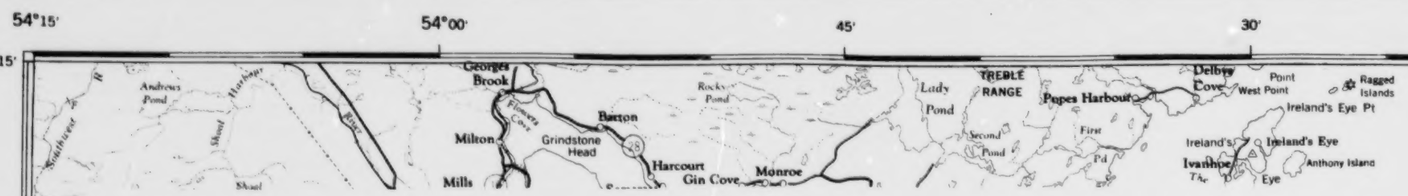
Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(L/min.) Range/Aver.	Use	OVBDN. Thick. Range/Aver. (m)	Geology Map Units
Patrick's Cove	4	23.9-51.8 (35.4)	3.1-4.8 (3.9) 1 N.D.	N.D.	9.1-13.7 (11.4) 1 N.D.	1 Do 3 Ind	0.3 3 N.D. brown topsoil	23/26/27
Riverhead	11	8.5-91.4 (48.5)	5.4-16.7 (8.3) 5 N.D.	N.D.	41.0-182 (67.0) 2 N.D.	4 Mu 1 Ind 3 DMAH 3 Do	4.0-11.3 (7.4) 7 N.D.	6
Salmonier	1	64	10.7	N.D.	9.1	1 Do	N.D.	6/8/11/5/1b/1a
St. Joseph's	5	36.6-68.6 (51.3)	6.4-15.2 (11.0) 1 N.D.	N.D.	3.4-54.6 (23.6) 1 N.D.	1 Ind 4 Do	5.2-11.9 (8.5) 3 N.D. gravel,small boulders, brown sand	6
St. Mary's	1	112.8	8.5	N.D.	N.D.	1 Do	N.D.	6/5
St. Vincent's	1	94.5	14.6	N.D.	27.3	1 Ind	N.D.	6

Electoral District - Waterford - Kenmount

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(l/min.) Range/Aver.	Use	OVBDN. Thick Range/Aver. (m)	Geology Map Units
Allison Drive	1	N.D.	6.7	N.D.	4.6	1 Do	3.0 gravel	6
Blackmarsh Rd.	1	45.7	N.D.	N.D.	N.D.	1 Com	N.D.	12/13/11/8
Bonavista St.	1	76.2	N.D.	N.D.	N.D.	1 Do	N.D.	12
Camp Rd.	2	27.4-99.1 (63.2)	2.1 1 N.D.	N.D.	N.D.	2 Do	N.D.	12/11/8
Donavans	2	21.3-30.5 (25.9)	N.D.	N.D.	N.D.	2 Do	N.D.	6/8(contact)

Electoral District - Waterford - Kenmount continued

Community	No. of wells	Well Depth Range/Aver. (m)	Cas. Length Range/Aver. (m)	St. Wat. Lev. Range/Aver. (m)	Yield(l/min.) Range/Aver.	Use	OVBDN. Thick Range/Aver. (m)	Geology Map Units
Jones Lane	1	57.9	N.D.	N.D.	N.D.	1 Do	N.D.	13/12
Kenmount Rd.	26	15.2-140.2 (51.3) 1 N.D.	2.1-15.5 (66.1) 8 N.D.	0.2-4.6 (3.1) 21 N.D.	9.1-91 (34.3) 14 N.D.	13 Com 4 Ind 9 Do	4.6-8.5 (6.6) 24 N.D.	12/11/8/6
Old Pennywell Rd.	3	18.3-42.7 (27.4)	N.D.	N.D.	N.D.	3 Do	N.D.	12/11/8
O'Leary Ave.	1	N.D.	N.D.	N.D.	N.D.	1 Com	N.D.	12/11/8/6
St. John's	1	N.D.	3.7	N.D.	13.7	1 Ind	2.1 gravel	13
Sweetwater	1	33.5	N.D.	- N.D.	13.7	1 Do	N.D.	N.D.
Thorburn Rd.	4	64.0 2 N.D.	2.1-6.7 (4.4) 1 N.D.	N.D.	4.6-54.6 (21.6) 1 N.D.	4 Do	1.2-6.1 (3.7) 1 N.D.	12/11/8/6/1a
Topsail Rd.	6	19.8 5 N.D.	2.7-6.7 (4.5) 2 N.D.	N.D.	2.3-22.6 (10.0) 1 N.D.	1 Com 5 Do	1.2-5.5 (3.0) 1 N.D. gravel,br. rock	12/11/8/6
Viking Rd.	1	61.0	N.D.	- N.D.	N.D.	1 Do	N.D.	12/11



PLEISTOCENE AND RECENT

10	*Beach and bar deposits: gravel, sand; generally modern, some raised shorelines in northwest part of area*
9	*Modern stream deposits: gravel, sand, silt*
8	*Bog and marsh deposits: peat and muck; in part sedge marsh and meadow*
7	*Outwash deposits: gravel, sand, silt; kames, outwash plain, valley train and delta*
6	*End moraine (till ridges perpendicular to ice motion): mostly till relatively high in fines, minor sand and gravel; commonly less stony than hummocky moraine and most ground moraine*
5	*Hummocky moraine (generally in irregular hillocks and short ridges): till, minor sand and gravel*
4	*Ablation moraine: stony till with little or no fines*
3	*Ground moraine, continuous cover: 3a, stony till 5 to 20 feet thick; 3b, patterned ground*
2	*Ground moraine, discontinuous cover: thin till cover with some ledges and knobs of rock outcrop; locally outcrops may be numerous*
1	*Undivided Proterozoic and minor Paleozoic rocks: bedrock outcrops numerous and may be of considerable extent; areas of shattered bedrock (felsenmeer) are common; patches of thin, generally very stony till separate outcrops*

Geological boundary (defined, approximate, assumed)

Glacial striae (direction of ice-movement known, unknown)

Intersecting glacial striae and grooves (numbers indicate relative age, 1 being the oldest)

Oriented ridge

Crag and tail

Eskers, small areas of associated kames: gravel, sand, silt,

SURFICIAL DEPOSIT HYDROSTRATIGRAPHIC UNITS

SURFICIAL HYDROSTRATIGRAPHIC UNIT	WELL YIELD L/min./(gpm) RANGE	WELL YIELD L/min./(gpm) MEAN	WELL DEPTH m/(feet) RANGE	WELL DEPTH m/(feet) MEAN	DATA SOURCE
UNIT S1 MORAINE LOW YIELD (2,3,4,5,6)**	0.0001-0.1* (0.0005-0.5)	<9.0 (<2.0)	N.D.	N.D.	
UNIT S2 OUTWASH DEPOSITS MODERATE TO HIGH YIELD (7)**	5.7-182. (1.25-40.)	40.6 (8.9)	8.5-65.5 (28-215)	20.9 (68.7)	2
	9.1-159.1 (2-35)		11.3-29.6 (37-97)		1

* Estimates, based on assumed hydraulic conductivities of 10^{-7} to 10^{-10} m/sec for a 2 m deep well, one metre in diameter with full drawdown.

** Numbers refer to surficial geology map units

Sources of Data

1. Hydrogeology of Trinity Bay Area. Water Resources Report 2-4, Newfoundland and Labrador Department of Environment

2. Hydrogeology of the Avalon Peninsula Area, (accompanying report to this map).

Sources of Information

1. Henderson, E.P., 1972: Surficial Geology of Avalon Peninsula, Newfoundland. Geological Survey of Canada, Memoir 368, and accompanying Surficial Geology Map, No. 1320A.

SURFICIAL HYDROGEOLOGY

AVALON PENINSULA AREA

SURFICIAL DEPOSIT HYDROSTRATIGRAPHIC UNITS

SURFICIAL HYDROSTRATIGRAPHIC UNIT	WELL YIELD L/min./(gpm) RANGE	WELL YIELD L/min./(gpm) MEAN	WELL DEPTH m/(feet) RANGE	WELL DEPTH m/(feet) MEAN	DATA SOURCE
UNIT S1 MORAINE LOW YIELD (2,3,4,5,6)**	0.0001-0.1* (0.0005-0.5)	<9.0 (<2.0)	N.D.	N.D.	
UNIT S2 OUTWASH DEPOSITS MODERATE TO HIGH YIELD (7)**	5.7-182. (1.25-40.)	40.6 (8.9)	8.5-65.5 (28-215)	20.9 (68.7)	2
	9.1-159.1 (2-35)		11.3-29.6 (37-97)		1

* Estimates, based on assumed hydraulic conductivities of 10^{-7} to 10^{-10} m/sec for a 2 m deep well, one metre in diameter with full drawdown.

** Numbers refer to surficial geology map units

Sources of Data

1. Hydrogeology of Trinity Bay Area. Water Resources Report 2-4, Newfoundland and Labrador Department of Environment

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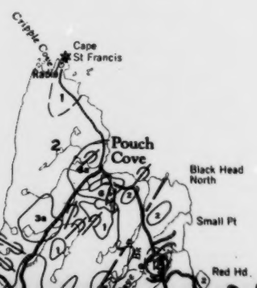
Sources of Information

1. Henderson, E.P., 1972: Surficial Geology of Avalon Peninsula, Newfoundland. Geological Survey of Canada, Memoir 368, and accompanying Surficial Geology Map, No. 1320A.

SURFICIAL HYDROGEOLOGY



2 — *Ground moraine, discontinuous cover: thin till cover with some ledges and knobs of rock outcrop; locally outcrops may be numerous*

1 — *Undivided Proterozoic and minor Paleozoic rocks: bedrock outcrops numerous and may be of considerable extent; areas of shattered bedrock (felsenmeer) are common; patches of thin, generally very stony till separate outcrops*

Geological boundary (defined, approximate, assumed)

Glacial striae (direction of ice-movement known, unknown)

Intersecting glacial striae and grooves (numbers indicate relative age, 1 being the oldest)

Oriented ridge

Crag and tail

Eskers, small areas of associated kames: gravel, sand, silt, till (direction of stream defined)

Meltwater channels

Crevasse fillings

Post-glacial raised shorelines and marine deposits (feet above mean sea level)

1. Hydrogeology of Trinity Bay Area. Water Resources Report 2-4, Newfoundland and Labrador Department of Environment

2. Hydrogeology of the Avalon Peninsula Area, (accompanying report to this map).

Sources of Information

1. Henderson, E.P., 1972: Surficial Geology of Avalon Peninsula, Newfoundland. Geological Survey of Canada, Memoir 368, and accompanying Surficial Geology Map, No. 1320A.

SURFICIAL HYDROGEOLOGY

AVALON PENINSULA AREA

(Geology by Henderson, 1972: Map 1320 A)

1984
MAP 1

Scale 1: 250,000

5 0 5 10 15 20 25

kilometres

1. Hydrogeology of Trinity Bay Area. Water Resources Report 2-4, Newfoundland and Labrador Department of Environment

2. Hydrogeology of the Avalon Peninsula Area, (accompanying report to this map).

Sources of Information

1. Henderson, E.P., 1972: Surficial Geology of Avalon Peninsula, Newfoundland. Geological Survey of Canada, Memoir 368, and accompanying Surficial Geology Map, No. 1320A.

SURFICIAL HYDROGEOLOGY

AVALON PENINSULA AREA

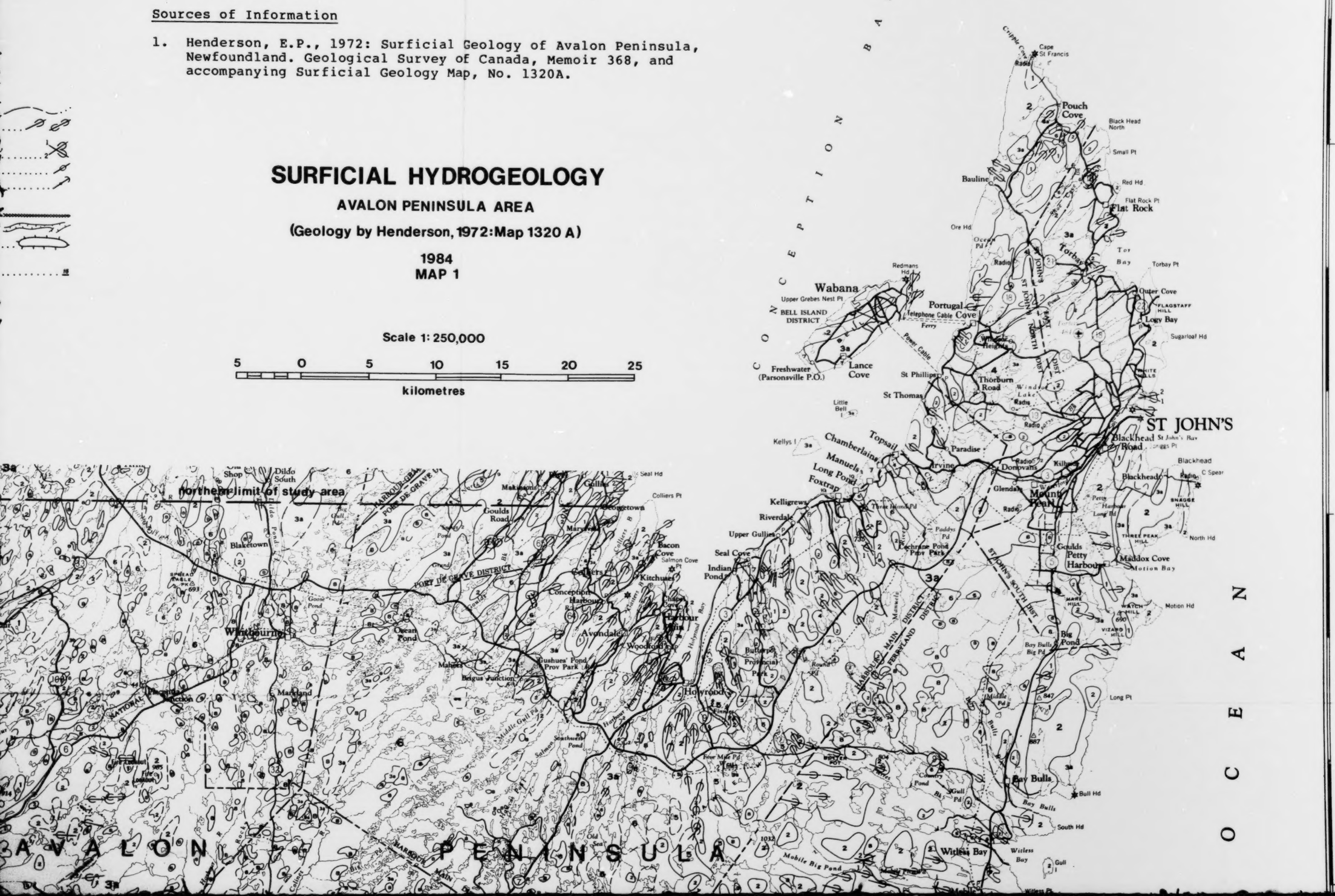
(Geology by Henderson, 1972: Map 1320 A)

1984
MAP 1

Scale 1: 250,000

5 0 5 10 15 20 25

kilometres



PLACENTIA

BAY

AVALON PENINSULA

ST MARY'S BAY

15'

47°00'

Long Pt
TOLT
Blue Pt
Red Island
882
Ragged Pt
PLACENTIA WEST
PLACENTIA EAST
TOM WALSH LOOKOUT
Long Harbour Hd
Ship Harbour
SUGARLOAF HILL
Fox I
250
Isaac Pt
Fox Harbour
Latine Pt
Argentia
Placentia Sound
Argentia Hr
Snalloway Pt
Mall Pt
Dunville
Jerseyside
Freshwater
Placentia
Pt Verde
Point Verde
385
Southeast Placentia
Black Pt
Little Barasway
Seal Pt
Great Barasway
KNORHOUR HILL
Ship Cove
394
Gooseberry Cove
574
1841
BEAVER POND HILLS
900
SUGARLOAF HILL
Patrick's Cove
Angels Cove
Erome Pt
Cuslett
Cuslett Cove
Cuslett Pt
Perch Cove
Cross Pt
St Bride's
Distress Cove
Island Hd
Norther Hd
Learn Cove
Briarly Cove
Cape St Mary's
Golden Bay
False Cape
Redland Pt
Bull Island Pt
Point Lance
Lance Cove
Bull and Cow
Trans-Canada Highway
Placentia Junction
National
Canadian
Maryland
Fox Harbour
Fire Lookout
Fire Lookout
Microwave 130
Colinet
Colinet Harbour
North Harbour
Harbour Main District
Harricott
St Catherine
Mount Carmel
Forest Field
New Bridge
Harricott Pt
Mitchells Brook
St Joseph's
North Harbour
Construction
SAWYERS HILL
902
KNOWLES HILL
SEPOY HILL
C Dog
Barachois Pt
Little Colinet Island
Mussel Pond Pt
O'Donnells
Great Colinet I
Admirals Beach
Mosquito
Colinet Passage
Shoal Bay Pt
Wild Cove
South Pt
Mall Bay
Riverhead
Beaver Beach
Frapeau Pt
Wild Cove
Lansecan Pt
Maggotty Pt
LANSECAN HILL
Wild Cove
East Hd
Red Hd
Beckford Hr
HARE HILL
LONGSTONE
Branch
Branch Cove
Branch Hd
Double Road Pt
St Mary's
La Haye Pt
Point La Haye
Gaskiers
Gaskiers Bay
HARE HILL
La Haye Pond
False Cape
Holyrood
Deer Pond
St Vincent's
Cape English
Holyrood Peter's Pond
Mahers
Beigus Junction
Tushues' Pond Prov Park
Holyrood
Provincial Park
Middle Gull Pd
Salmon Southwest Pond
Five Mile Pd
Old Sen
Mobile Big Pond
Paradise Pond
Harbour Pd
Parkers Pd
Mount Carmel Pond
Franks Pd
Saunders Ponds
Penstock
Power House
Cape Broyle
Penstock
Radio 200
Canal
Calvert
Aquaforte
Aquaforte Hr
Fermeuse
Kingman's
Renews
Northern
Burnt Pt
Cappahayden
Seal Cove
Black Hd
Cape Ballard
Radio 1350 Tower
Northwest Pond
Northwest Pond
Deer
Peter's
Holyrood
Northwest
Northwest Bk
Mount Carmel Mine
Pond
Pond
Pond

AVALON PENINSULA

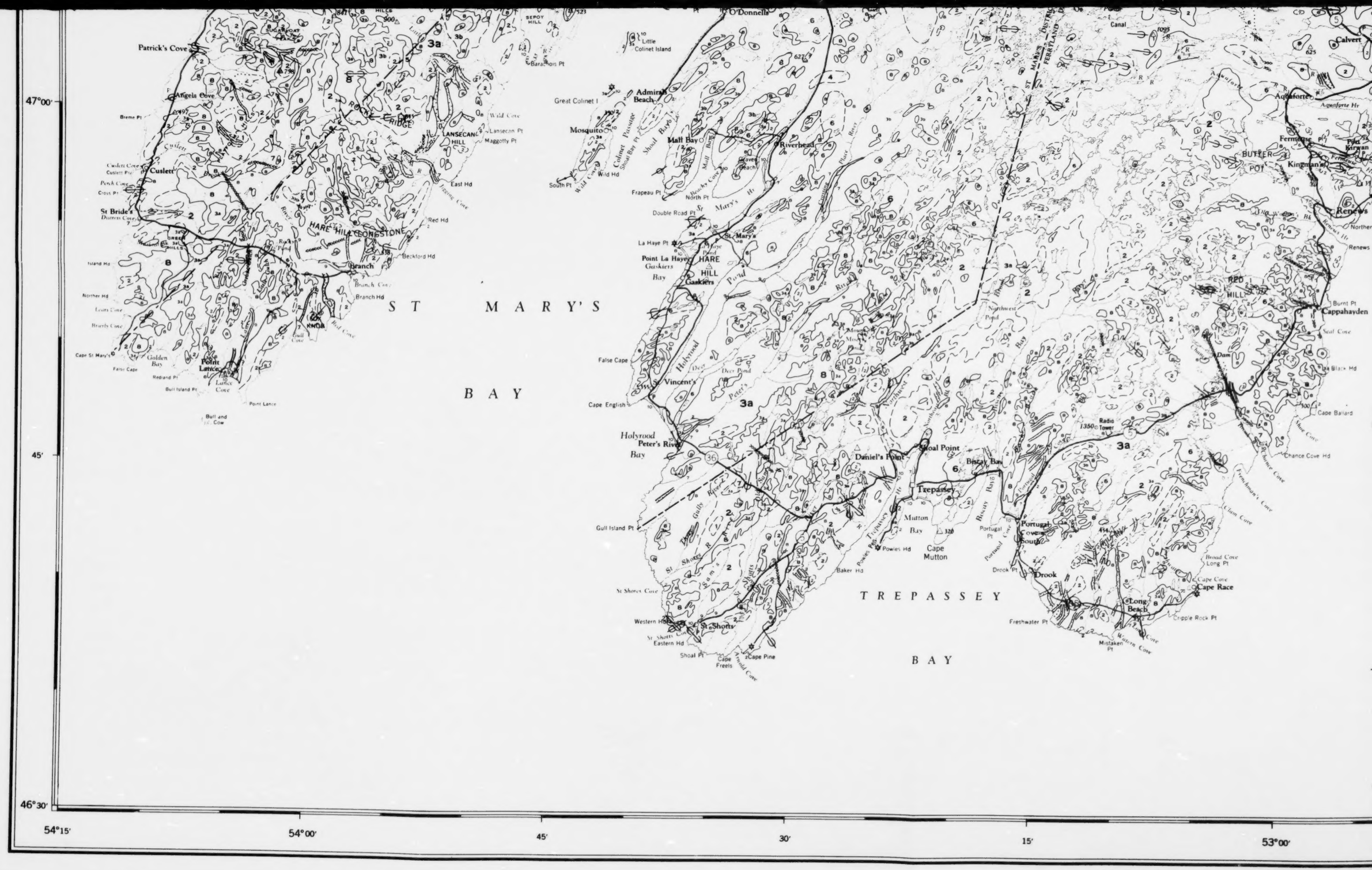
MARY'S BAY

OCEANIC

HARBOUR MAIN DISTRICT

ST MARY'S FERRYLAND DISTRICT

Placentia Junction
Marland
Malaks
Brigus Junction
Bushues' Pond Prov Park
Woodford's Pond
Holyrood
Butterpot Provincial Park
Big Pond
Bay Bulls Big Pd
Long Pt
Bay Bulls
Bull Hd
South Hd
Witless Bay
Witless Bay Pond
Witless Pt
Mobile
Tors Cove
Burnt Cove
La Manche Prov Park
Bauline East
C Neddick
Brigus South
Admiral's Cove
Cape Broyle
Cape Broyle Harbour
North Pt
C Broyle
Calvert
Ferryland
Ferryland Hd
Aquaforte
Aquaforte Hr
Fermeuse
Kingman's Cove
Bear Cove Pt
Renews
Renews Hd
Northern Hd
Cappahayden
Seal Cove
Black Hd
Cape Ballard
Colinet
Harricott
St Catherine's
Mount Carmel
Forest Field
New Bridge
Mitchells Brook
St Joseph's
North Harbour
Harricott Pt
Construction
Microwave 130
Colinet Harbour
Mussel Pond Pt
O'Donnells
Little Colinet Island
Barachois Pt
Great Colinet I
Admirals Beach
Mosquito
Mall Bay
Riverhead
Wild Cove
Lansecan Pt
Maggotty Pt
Wild Hd
South Pt
Frapeau Pt
North Pt
Double Road Pt
St Mary's
La Haye Pt
Point La Haye
Gaskiers
HARE HILL
Gaskiers Pond
False Cape
St Vincent's
Cape English
Holyrood Deer Pond
Peters Pond
Northwest Pond
Mount Misery
Canal
Radio 1350
Radio 200
Mount Carmel Pond
Saunders Ponds
Power House
Penstock
Franks Pd
Little Harbour Pd
Middle Gull Pd
Salmonier River
Colinet River
Harricott B
Little Harbour River
Cape Broyle River
Aquaforte River
Northwest River
Deer Pond River
Mall Bay Brook
Beaches Cove Brook
Mobile Big Pond
Paradise Pond
Butler Pd
Old Sea Pond
Southern Pond
Fever Mede Pd
Country Pond
Gull Pd
Bay Bulls
Middle Pd
Round Pd
Harbour Main Pond
Salmon Pond
Gushues Pond
Harbour Main River
Middle Gull Pd
Salmon Pond
Colinet Passage
Shoal Bay
Shoal Bay Pt
Colinet Harbour
Mall Bay
Beaches Cove
Mary's Hr
Colinet River
Northwest Pond
Deer Pond
Peters Pond
Holyrood Deer Pond
Aquaforte Hr
Renews Hr
Cuttern Bay
Calvert Bay
Fermeuse Pond
Kingman's Cove
Bear Cove
Northern Hd
Chance Bay
Bald Hd
Lawlor Bay
Black Hd
Witless Bay
Witless Bay Pond
Mobile Pond
Tors Cove Pond
Tinker Pt
Great I
Gull I
Mobile Hr
Mobile Pond
Mount Carmel Pond
Saunders Ponds
Power House
Penstock
Cape Broyle Harbour
Cape Broyle
Brigus Hd
Bull Hd
Ferryland Hd
Bear Cove Pt
Renews Hd
Northern Hd
Burnt Pt
Seal Cove
Black Hd
Cape Ballard
Dam
Gravel Beach
Wild Cove
Shoal Bay Pt
Double Road Pt
La Haye Pond
Gaskiers Pond
Northwest Pond
Deer Pond
Peters Pond
Holyrood Deer Pond
Mount Misery
Canal
Dam
Radio 1350 Tower
Radio 200
Penstock
Power House
Saunders Ponds
Franks Pd
Little Harbour Pd
Middle Gull Pd
Salmon Pond
Gushues Pond
Harbour Main River
Southern Pond
Fever Mede Pd
Country Pond
Gull Pd
Bay Bulls
Middle Pd
Round Pd
Harbour Main Pond
Paradise Pond
Butler Pd
Old Sea Pond
Mobile Big Pond
Witless Bay Pond
Tors Cove Pond
Tinker Pt
Great I
Gull I
Mobile Hr
Witless Pt
Witless Bay
Bull Hd
South Hd
Bay Bulls


ST MARY'S BAY
TREPASSEY BAY
Patrick's Cove
Angela Cove
Cuslett
St Bride's
Point Lance
Bull and Cow
Golden Bay
Branch
Red Hd
Beckford Hd
Branch Hd
Lansecan Hill
Lansecan Pt
Maggotty Pt
East Hd
Wild Cove
Admirals Beach
Great Colinet I
Little Colinet Island
Mosquito
Mall Bay
Riverhead
Frapeau Pt
South Pt
North Pt
Double Road Pt
St Mary's
La Haye Pt
Point La Haye
Gaskiers
Gaskiers Bay
False Cape
St Vincent's
Cape English
Holyrood
Peter's River
Bay
Gull Island Pt
St Shotts
Western Hd
Eastern Hd
Shoal Pt
Cape Pine
Cape Freels
Daniel's Point
Coal Point
Trepassey
Mutton Bay
Cape Mutton
Powles Hd
Baker Hd
Portugal Cove South
Portugal Pt
Drook
Drook Pt
Freshwater Pt
Long Beach
Cape Race
Cripple Rock Pt
Mistaken Pt
Aquaforte
Calvert
Fermeuse
Kingman's
Renews
Cappahayden
Seal Cove
Black Hd
Cape Ballard
Chance Cove Hd
Radio Tower
1350
47°00′
45′
46°30′
54°15′
54°00′
45′
30′
15′
53°00′

Bonnells
Little Colinet Island
Barachois Pt
Great Colinet I
Admirals Beach
Wild Cove
Lansecan Pt
Maggotty Pt
Mosquito
Colinet Passage
Shoal Bay Pt
Shoal Bay
Mall Bay
Riverhead
Beaver Beach
South Pt
Wild Cove
Wild Hd
Frapeau Pt
North Pt
Mall Beach
Mall Bay
Double Road Pt
St. Mary's Hr
St. Mary's
La Haye Pt
Point La Haye
Gaskiers
Bay
HARE HILL
Gaskiers
Pond
Canal
St. Mary's Bay
Ferryland District
Calvert
Calvert Bay
C Broyle
Ferryland
Ferryland Hd
Aquaforte
Aquaforte Hr
Fermeuse
Kingman
Bald Hd
Northern Hd
Bear Cove Hd
Bear Cove Pt
Renews
Renews Hd
Renews Hr
Lawlor Bay
Black Hd
Chance Bay
BUTTER POT
RED HILL
Burnt Pt
Cappahayden
Seal Cove
Black Hd
Cape Ballard
Chance Cove Hd
Chance Cove
Frenchman's Cove
Ullam Cove
Broad Cove
Long Pt
Cape Cove
Cape Race
Cripple Rock Pt
Long Beach
Western Cove
Mistaken Pt
Freshwater Pt
Drook
Drook Pt
Portugal Cove South
Portugal Pt
Portugal Cove
Biscay Bay
Trepassey
Mutton Bay
Cape Mutton
Powles Hd
Baker Hd
Powles Beach
Trepassey Hr
Shoal Point
Brazil Bay
Daniel's Point
Radio Tower
1350
Holyrood
Peter's River
Bay
False Cape
Cape English
St. Vincent's
Holyrood Pond
Deer Pond
Peter's River
Gull Island Pt
Gully
Gully River
St. Shotts
St. Shotts Cove
Western Hd
St. Shotts
Eastern Hd
Shoal Pt
Cape Freels
Arnold Cove
Cape Pine
Northwest Pond
Mount Misery
Misery Pond
Dam
Chance Pond
Mine Cove
MARY'S BAY
TREPASSEY BAY
ATLANTIC
3a
6
8
36
47°00′
45′
46°30′
45′
30′
15′
53°00′
45′
52°30′

LEGEND

TRIASSIC

36 Diabase dykes along Avalon Magnetic Lineament

DEVONIAN AND EARLIER

35 Diabase dykes of presumed Devonian age; 35a Iona Islands Plutonic Suite (?Dev.)

34 Diabase sills of presumed Silurian age

ORDOVICIAN

LOWER ORDOVICIAN

WABANA GROUP (33)

33 Shale and sandstone, beds of oolitic ironstone

BELL ISLAND GROUP (32)

32 Sandstone and shale, beds of oolitic ironstone; 32a white quartzose sandstone

31 CLARENVILLE FORMATION: grey micaceous shale

CAMBRIAN

UPPER CAMBRIAN

30 ELLIOTT COVE FORMATION: black and greenish grey micaceous shale, minor limestone

MIDDLE CAMBRIAN

29 Diabase and gabbro intrusions

28 CHAMBERLAINS BROOK AND MANUELS RIVER FORMATIONS: black, grey and green shale, manganiferous beds at base; 28a pillow lava, breccia and tuff

LOWER CAMBRIAN

27 BONAVISTA, SMITH POINT AND BRIGUS FORMATIONS: red and green shale, pink algal limestone

26 RANDOM FORMATION: white quartzose sandstone with interbeds of arkose and siltstone; minor conglomerate at base

LATE PRECAMBRIAN

SIGNAL HILL GROUP (15-21)

21 CAPE BALLARD FORMATION:
upper part: grey sandstone and quartz granule conglomerate;
lower part: grey shale and siltstone

19 20 19 BLACKHEAD FORMATION: red and grey sandstone, siltstone, shale

20 FLAT ROCK COVE FORMATION: grey conglomerate overlain by red breccia

18 CUCKOLD FORMATION: red conglomerate and sandstone (includes similar rocks at Bay de Verde);
18a Maddox Cove Member at top: red siltstone and sandstone (includes similar rocks in eastern Trinity Bay)

17 QUIDI VIDI FORMATION: red and green sandstone and siltstone, minor pebble conglomerate (includes similar rocks at Whiteway, Maturin Ponds and Ferryland Head)

16 GIBBETT HILL FORMATION: thick bedded light grey sandstone, thin bedded greenish grey sandstone, siltstone and tuff (includes similar rocks at Halls Town and Big Head)

15 CAPPAHAYDEN FORMATION: laminated grey siltstone

14 BULL ARM FORMATION: bimodal volcanic rocks with minor clastic sedimentary rocks;
14a mainly basaltic flows and pyroclastic rocks;
14b mainly felsic flows and pyroclastic rocks

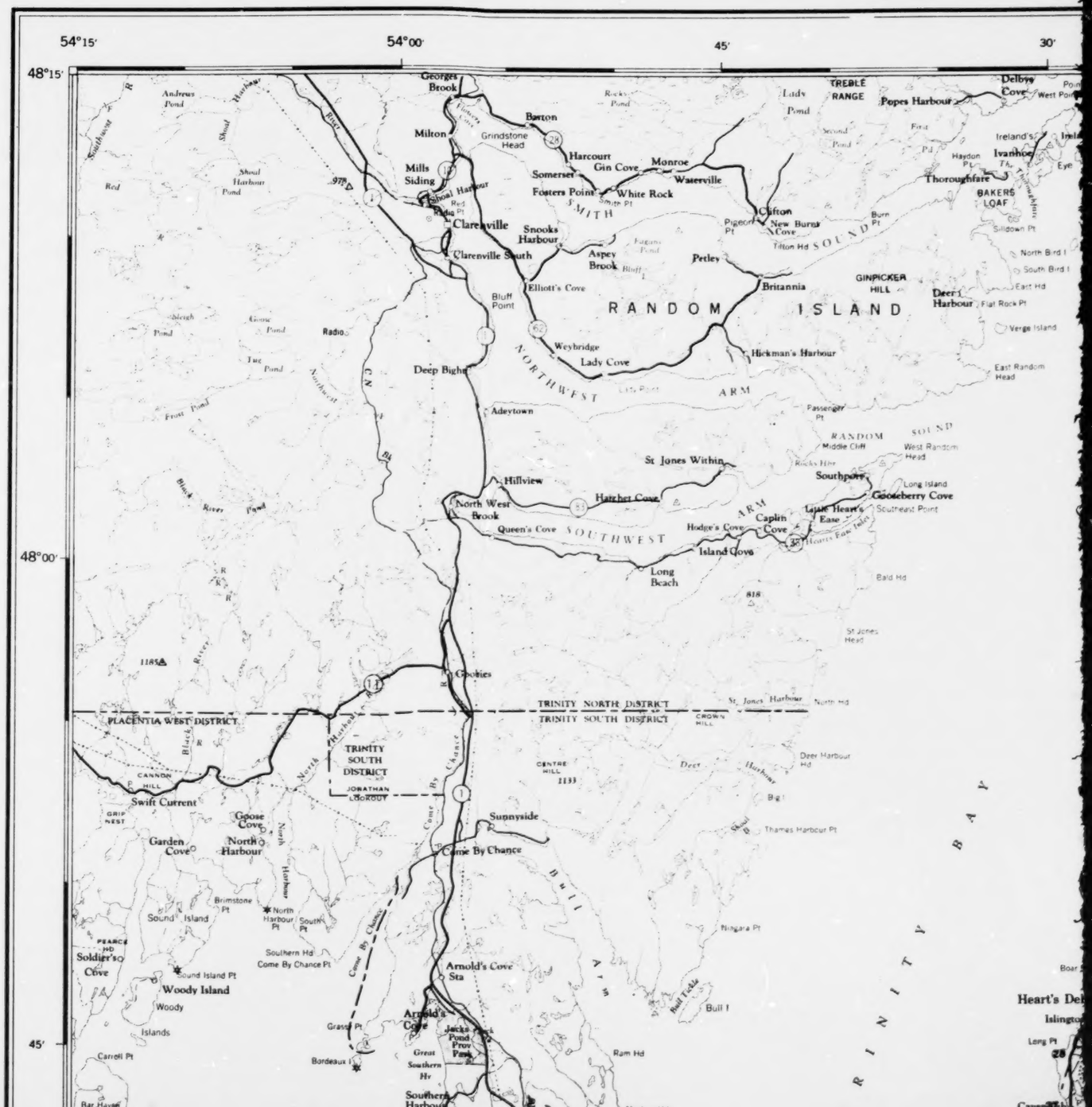
MUSGRAVETOWN AND 'DILDO' GROUPS (14;22-25)

24 25 24 NEW PERLICAN FORMATION: red conglomerate

25 CROWN HILL FORMATION: red conglomerate

23 HEART'S DESIRE FORMATION: olive green sandstone

22 HEART'S CONTENT FORMATION: grey wispy-bedded shale and sandstone, minor grey pebble conglomerate



54°15'
54°00'
45'
30'
15'
53°00'
45'
48°15'
48°00'
45'
Georges Brook
Burton
Milton
Grindstone Head
Harcourt
Gin Cove
Monroe
Waterville
Somerset
Fosters Point
White Rock
Mills Siding
Clarenville
Snooks Harbour
Clarenville South
Aspey Brook
Petley
Britannia
Elliott's Cove
Weybridge
Lady Cove
Deep Bight
Adeytown
Hillview
North West Brook
Queen's Cove
Hatcher Cove
St Jones Within
Southport
Long Island
Gooseberry Cove
Southeast Point
Hodge's Cove
Caplin Cove
Island Cove
Long Beach
Goobies
Sunnyside
Come By Chance
Arnold's Cove
Woody Island
Swift Current
Goose Cove
Garden Cove
North Harbour
Soldier's Cove
Bordeaux
Southern Harbour
Masters Hd
Bull I
Ram Hd
Grassy Pt
Carroll Pt
Bay Haven
Southern Hd
Come By Chance Pt
Brimstone Pt
Sound Island
Sound Island Pt
Woody
Islands
Niagara Pt
Thames Harbour Pt
Deer Harbour Hd
North Hd
St Jones Harbour
St Jones Head
Bird Hd
Middle Cliff
West Random Head
Rocks Hbr
Long Island
Southeast Point
Hearts Ease Island
Hearts Ease
Caplin Cove
Island Cove
Long Beach
Bird Hd
St Jones Head
TREBLE RANGE
Popes Harbour
Delbys Cove
West Point
Ragged Islands
Ireland's Eye Pt
Ireland's Eye
Anthony Island
Green Island
Haydon Pt
Ivanhoe
Thoroughfare
BAKERS LOAF
Sildown Pt
Duck Island
North Bird I
South Bird I
East Hd
Deer Harbour
Flat Rock Pt
Verge Island
East Random Head
GINPICKER HILL
Clifton
New Burns Cove
Pigeon Pt
Titon Hd
Burn Pt
Bluff Point
Bluff I
Fogans Pond
Passenger Pt
Hickman's Harbour
Lady Point
Radio
Deep Bight
Adeytown
Hillview
North West Brook
Queen's Cove
Hatcher Cove
St Jones Within
Southport
Long Island
Gooseberry Cove
Southeast Point
Hodge's Cove
Caplin Cove
Island Cove
Long Beach
Goobies
Sunnyside
Come By Chance
Arnold's Cove
Woody Island
Swift Current
Goose Cove
Garden Cove
North Harbour
Soldier's Cove
Bordeaux
Southern Harbour
Masters Hd
Bull I
Ram Hd
Grassy Pt
Carroll Pt
Bay Haven
Southern Hd
Come By Chance Pt
Brimstone Pt
Sound Island
Sound Island Pt
Woody
Islands
Niagara Pt
Thames Harbour Pt
Deer Harbour Hd
North Hd
St Jones Harbour
St Jones Head
Bird Hd
Middle Cliff
West Random Head
Rocks Hbr
Long Island
Southeast Point
Hearts Ease Island
Hearts Ease

45′ 30′ 15′ 53°00′ 45′ 52°30′ 48°15′ 48°00′ 45′

TREBLE RANGE
Lady Pond
Second Pond
First Pond
Popes Harbour
Delbye Cove
Point West Point
Ragged Islands
Ireland's Eye Pt
Ireland's Eye
Anthony Island
Green Island
Haydon Pt
Ivanhoe
Eye
Thoroughfare
BAKERS LOAF
Monroe
Waterville
White Rock Pt
Clifton
Pigeon Pt
New Burns Cove
Burn Pt
Tilton Hd
SOUND
Fagans Pond
Petley
Bluff L
Britannia
GINPICKER HILL
Deer I Harbour
Flat Rock Pt
North Bird I
South Bird I
East Hd
Duck Island
Silldown Pt
ANDOM ISLAND
Verge Island
Hickman's Harbour
East Random Head
ARM
Passenger Pt
RANDOM SOUND
Middle Cliff
West Random Head
St Jones Within
Rocks Hbr
Southport
Long Island
Gooseberry Cove
Southeast Point
Hodge's Cove
Caplin Cove
Little Heart's Ease
Heart's Ease Inlet
WEST ARM
Island Cove
Long Beach
Bald Hd
St Jones Head
St Jones Harbour
North Hd
CROWN HILL
Deer Harbour Hd
Thames Harbour Pt
Niagara Pt
Bull I
TRINITY BAY
Greater Point
Breakheart Point
Bracies Cove
BACCALIEU
Giddening Head
Red Head
TICKLE
Baccalieu Island
Kings Head
Daniel's Cove
Red Head Cove
BAY
Cooks Cove
Skerwink Point
Scott Point
Perlican Island
Old Perlican
Bull Gulch Point
Bay de Verde
Low Point
Sylvane Point
New Melbourne
White Point
Lead Cove
Sibleys Cove
BAY DE VERDE PENINSULA
Caplin Cove
Brownsdale
Flambro Head
New Chelsea
Hant's Harbour
Island Pond
Lower Island Cove
Kings Head Pond
Pomeroy Pond
Winterton
Western Pond
Burnt Point
Gull Island
Northern Bay
Fox Pt
Jeans Hd
New Perlican
Ochre Pit Cove
Western Bay Hd
Western Bay
Heart's Content
Adams Cove
Blackhead
Broad Cove
SHUFFLE BOARD
Heart's Content Cove Pd
Sputtercer Island Pd
Broad Cove
Kingston
Gannet Pt
Seal Cove
HANGING HILL
BAY DE VERDE DISTRICT
Perry's Cove
Boar Pt
Salmon Cove Hd
Salmon Cove
Heart's Delight
Islington
Victoria
Freshwater
Long Pt
LOOKOUT
Gull Pd
Carbonear
Carbonear Bay
Carbonear I
Bristol's Hope
Cape St Francis
Pouch Cove
Black Head North
Small Pt
Bauline
Red Hd

25 CROWN HILL FORMATION: red conglomerate

21 CAPE BALLARD FORMATION:
upper part: grey sandstone and quartz granule conglomerate;
lower part: grey shale and siltstone

23 HEART'S DESIRE FORMATION: olive green sandstone

19 20 19 BLACKHEAD FORMATION: red and grey sandstone, siltstone, shale

20 FLAT ROCK COVE FORMATION: grey conglomerate overlain by red breccia

22 HEART'S CONTENT FORMATION: grey wispy-bedded shale and sandstone, minor grey pebble conglomerate

18 CUCKOLD FORMATION: red conglomerate and sandstone (includes similar rocks at Bay de Verde);
18a Maddox Cove Member at top: red siltstone and sandstone (includes similar rocks in eastern Trinity Bay)

17 QUIDI VIDI FORMATION: red and green sandstone and siltstone, minor pebble conglomerate (includes similar rocks at Whiteway, Maturin Ponds and Ferryland Head)

16 GIBBETT HILL FORMATION: thick bedded light grey sandstone, thin bedded greenish grey sandstone, siltstone and tuff (includes similar rocks at Halls Town and Big Head)

15 CAPPAHAYDEN FORMATION: laminated grey siltstone

14 BULL ARM FORMATION: bimodal volcanic rocks with minor clastic sedimentary rocks;
14a mainly basaltic flows and pyroclastic rocks;
14b mainly felsic flows and pyroclastic rocks

ST. JOHN'S GROUP (11-13)

13 RENEWS HEAD FORMATION: thin, lenticular, bedded dark grey sandstone with minor shale

12 FERMEUSE FORMATION: grey to black shale with thin lenses of buff-weathering sandstone and siltstone. Mainly light grey thin-bedded and contorted shale and sandstone toward base

11 TREPASSEY FORMATION: medium-to-thin-bedded, graded, grey sandstone and shale, tuff

10 WHALESBACK GABBRO (AND EQUIVALENTS): fine to medium grained diabase and gabbro

9 CONNECTING POINT GROUP (9)

Green to black shale; siliceous siltstone and sandstone; minor conglomerate; numerous mafic sills and dykes probably related to 14

CONCEPTION GROUP (4-8)

8 MISTAKEN POINT FORMATION: medium-bedded grey to pink sandstone and green to purple and red shale, minor thin tuff horizons. Contains Precambrian fossils toward its top

7 BRISCAL FORMATION: thick-bedded coarse grey sandstone, olive to grey argillite, red arkosic sandstone; local units of thin-bedded grey siltstone and shale

6 DROOK FORMATION: green siliceous siltstone and sandstone, silicified tuff;
6a Clam Cove Member, grey pebbly siltstone and shale
6b Biscay Bay Member, altered green to purplish basalt
6c Peter's River Member, grey, coarse-grained turbiditic sandstone
6d Cape English Member, grey to red turbiditic sandstone

5 GASKIERS FORMATION: grey mixtite (tillite), red mixtite overlain by red mudstone at top;
5a South Point Member, red agglomerate

4 MALL BAY FORMATION: green siliceous siltstone, argillite and tuff, thick-bedded tuffaceous sandstone, white quartzose sandstone and minor limestone

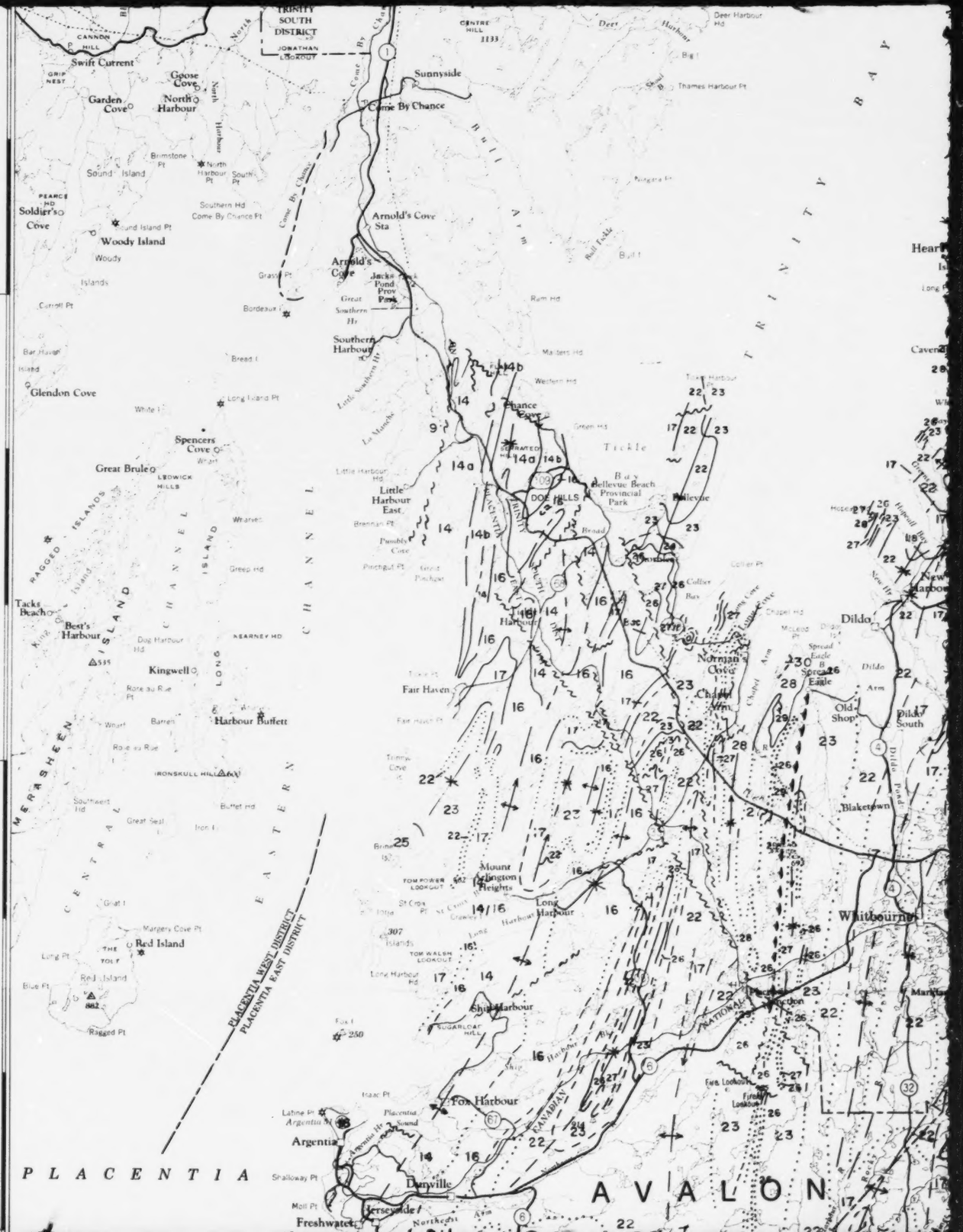
2 3 HOLYROOD PLUTONIC SUITE (2-3)

3 mainly pink granite, aplite
2 mainly monzonite, diorite, gabbro

1 HARBOUR MAIN GROUP (1)

Bimodal volcanic rocks with minor clastic sedimentary rocks:
1a altered green to purplish basalt
1b red rhyolite and welded tuff
1c pink to grey felsic tuff and agglomerate, arkose, siltstone and conglomerate
1d mainly felsic and mafic intrusive rocks

Geological boundary (defined, approximate, assumed) ....
Bedding .....
Fault (defined, approximate, assumed) .....
Synclinal axis with direction of plunge .....
Anticlinal axis with direction of plunge .....



PLACENTIA WEST DISTRICT
TRINITY SOUTH DISTRICT
Swift Current
Goose Cove
Garden Cove
North Harbour
Sunnyside
Come By Chance
Deer Harbour
Thames Harbour Pt
Woody Island
Armold's Cove Sta
Armold's Cove
Southern Harbour
Great Brule
Spencers Cove
Little Harbour East
Bellevue Beach Provincial Park
Bellevue
Tickle Bay
Chance Cove
Western Hd
Masters Hd
Ram Hd
Bull I
Hill Run
Trinity Bay
New Perlican
Heart's Content
Heart's Delight
Islington
Caverton
Whiteway
Green's Harbour
New Harbour
Dildo
Old Shop
Blaketown
Whitbourne
Maryland
Harbour Grace
Carbonear
Bay de Verde District
Carbonear District
Harbour Grace District
Port de Grave District
Western Bay
Ochre Pit Cove
Blackhead
Broad Cove
Kingston
Perry's Cove
Salmon Cove
Freshwater
Bristol's Hope
Old Shop Pt
Harbour Grace Islands
Bryants Cove
Upper Island Cove
Bishop's Cove
Spaniard's Bay
Shearstown
Bay Roberts
Coley's Point South
Bareneed
Butlerville
Clarke's Beach
Cupids
Brigus
Brigus Junction
Gould's Road
Seal Cove
Indian Pond
Bacon Cove
Conception Bay
Pouch Cove
Flat Rock
Torbay
Portugal Cove
Wabana
Bell Island District
Lance Cove
Freshwater (Parsonsville P.O.)
St Phillips
St Thomas
Thorburn Road
Topsail
Chamberlains
Manuels
Long Pond
Foxtrap
Paradise
Irving
Mount Pearl
Glendale
Goulds
Petty Harbour
Kelligrews
Riverdale
Upper Gullies
Bay Bulls
Witless Bay
Witless Bay Hd
Bull Hd
South Hd
Placentia West District
Placentia East District
Argentia
Dunville
Fox Harbour
Long Harbour
Mount Arlington Heights
Shit Harbour
Sugarloaf Hill
Red Island
Goat I
Margery Cove Pt
Rogged Pt
Fox I
Best's Harbour
Kingwell
Harbour Buffett
Fair Haven
Norman's Cove
Chapel Arm
Dildo Arm
Dildo South
Spread Eagle
Old Shop
Ocean Pond
Goose Pond
Gull Pd
Tilton
Spaniard's Bay
Mercer's Cove
Ship Cove
Bareneed
Clarke's Beach
Cupids
Brigus

AVALON PENINSULA

TRINITY BAY

CONCEPTION BAY

ATLANTIC OCEAN

New Perlican
Heart's Content
Heart's Delight
Islington
Cavendish
Whiteway
Green's Harbour
Ochre Pit Cove
Western Bay
Adam's Cove
Blackhead
Broad Cove
Kingston
Perry's Cove
Salmon Cove
Victoria
Freshwater
Carbonear
Bristol's Hope
Harbour Grace
Harbour Grace (Southside)
Upper Island Cove
Bishop's Cove
Tilton
Spaniard's Bay
Bay Roberts
Coley's Point South
Shearstown
Butterville
Clarke's Beach
Brigus
Cupids
Dildo
New Harbour
Norman's Cove
Old Shop
Blaketown
Whitbourne
Markland
Long Harbour
Ocean Pond
Deer Harbour Hd
Thames Harbour Pt
Niagara Pt
Bull I
Ram Hd
Masters Hd
Western Hd
Green Hd
Tickle Bay
Bellevue Beach Provincial Park
Bellevue
Collier Pt
Collier Bay
Chapel Hd
Spread Eagle
Chapel Arm
Dildo Arm
Dildo South
Dildo Pond
Goose Pond
Fire Lookout
Pt. La Haye
Pt. Verde
Pt. Grave
Pt. Lance
Pt. Verde
Pt. Verde
Pt. Verde

Bimodal volcanic rocks with minor clastic sedimentary rocks:
1a altered green to purplish basalt
1b red rhyolite and welded tuff
1c pink to grey felsic tuff and agglomerate, arkose, siltstone and conglomerate
1d mainly felsic and mafic intrusive rocks

Geological boundary (defined, approximate, assumed ....
Bedding .....
Fault (defined, approximate, assumed) .....
Synclinal axis with direction of plunge .....
Anticlinal axis with direction of plunge .....

Major contributors of maps used in compilation or significantly revised during present project:
Map 1018A Torbay ..... E. R. Rose (1952)
Map 1035A Harbour Grace ..... R. D. Hutchinson (1953)
Map 1168A Whitbourne ..... W. D. McCartney (1967)
Map 1468A Trepassey ..... H. Williams & A. F. King (1979)

BEDROCK GEOLOGY

AVALON PENINSULA AREA

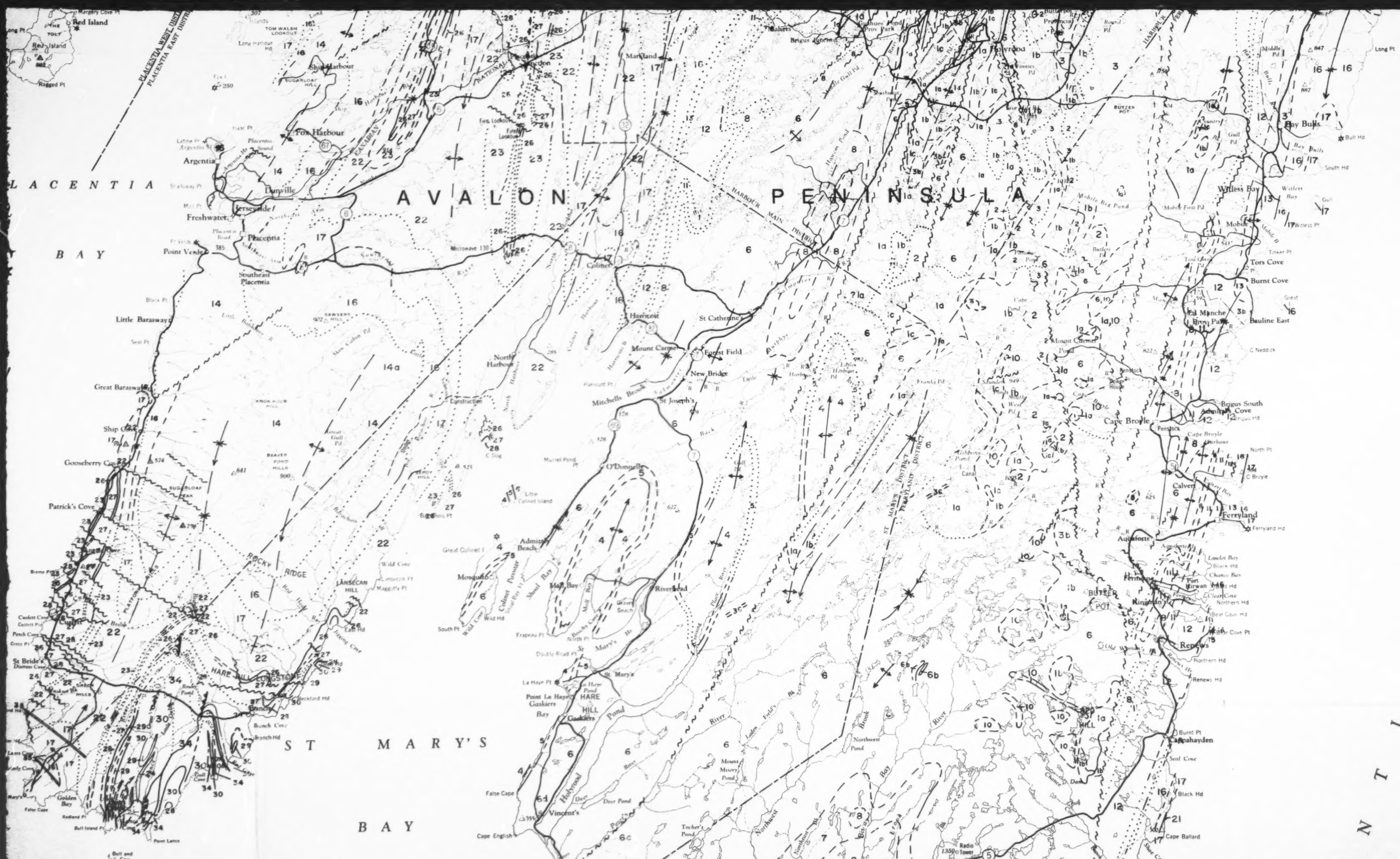
by

A. KING

1984
MAP 2

Scale 1:250,000

Miles 4 0 4 8 12 Miles
Kilometres 6 0 6 12 18 Kilometres


PLACENTIA
BAY
AVALON PENINSULA
ST MARY'S BAY
Red Island
Margery Cove Pt
Ragged Pt
Long Pt
PLACENTIA WEST DISTRICT
PLACENTIA EAST DISTRICT
Ship Harbour
Fox Harbour
Argentia
Dunville
Jerseyside
Freshwater
Placentia
Point Verde
Southeast Placentia
Little Barasway
Great Barasway
Ship Cove
Gooseberry Cove
Patrick's Cove
St Bride's
Golden Bay
Redland Pt
Bull Island Pt
Point Lance
Maryland
Colinet
Harricott
St Catherine's
Mount Carmel
Forest Field
New Bridge
North Harbour
St Joseph's
O'Donnells
Admirals Beach
Great Colinet I
Mosquito
Mall Bay
Riverhead
St Mary's
La Haye Pt
Point La Haye
Gaskiers
Gaskiers Bay
HARE HILL
Pond
Holyrood
False Cape
St Vincent's
Cape English
Deer Pond
Mitchells Brook
Mosquito Pond
Northwest Pond
Mount Misery Pond
Tocher's Pond
Brigus Junction
Cahers
Gibbons Pond
Provincial
Round Pd
Middle Pd
Bay Bulls
Bull Hd
South Hd
Witless Bay
Witless Pt
Mobile
Tors Cove
Burnt Cove
Bauline East
Bauline
Mount Carmel
Pond
Cape Broyle
Penstock
Cape Broyle Harbour
North Pt
Calvert
Ferryland
Ferryland Hd
Aquaforte
Lawlor Bay
Black Hd
Chance Bay
Port Kirwan
Clear Cove
Northern Hd
Bear Cove Hd
Bear Cove Pt
Renews
Renews Hd
Northern Hd
Rinvyan
Burnt Pt
Seal Cove
Black Hd
Cape Ballard
Brigus South
Admirals Cove
Tinker Pt
Middle Head
Mobile Big Pond
Mobile First Pd
Butter Pot
Harbour Main Pd
Harbour Main District
St Mary's Ferryland District
Placentia Sound
Placentia Harbour
Placentia Bay
Argentia Pt
Mall Pt
Black Pt
Seal Pt
Skerry Cove Pd
Great Gull Pd
Little Gull Pd
Little Barasway
Great Barasway
Ship Cove
Gooseberry Cove
Patrick's Cove
Breme Pt
Caulkett Cove
Caulkett Pt
Perch Cove
Cross Pt
Cuslett
Cuslett Brook
Placentia River
Rocky Ridge
Lansecan Hill
Wild Cove
Wild Hd
Maggotty Pt
East Hd
Freezing Cove
Hare Hill
Stone
Brandy
Branch
Branch Cove
Branch Hd
Golden Bay
False Cape
Bull Island Pt
Point Lance
Gull Cove
Gull Cove Pt
Mosquito
Wild Cove
Wild Hd
South Pt
Colinet Island
Colinet Harbour
Colinet Peninsula
Colinet River
Colinet Pond
Colinet Pond Pt
Colinet Pond Brook
Colinet Pond Dam
Colinet Pond Dam Pd
Colinet Pond Dam Pd
Colinet Pond Dam Pd

AVALON PENINSULA

MARY'S BAY

OCEANTIC

HARBOUR MAIN DISTRICT

ST MARY'S PLACENTIA DISTRICT

BUTTER POT

Markland
Admiral's Beach
Mosquito
Mall Bay
Riverhead
Colinet
Harricott
St Catherine's
Mount Carmel
Forest Field
New Bridge
North Harbour
Mitchells Brook
St Joseph's
O'Donnells
Construction
Mussel Pond
Great Colinet I.
Little Colinet Island
Wild Cove
Lamaline Pt
Magotty Pt
South Pt
Wild Hd
Frapeau Pt
North Pt
Double Road Pt
St Mary's
La Haye Pt
La Haye Pond
Point La Haye
Gaskiers
Gaskiers Bay
HARE HILL
Pond
False Cape
Holyrood
Deer
Deer Pond
Vincent's
Cape English
Microwave 130
Fire Lookout
Firefly Lookout
Colinet Harbour
Colinet Island
Colinet Passage
Shoal Bay
Mall Bay
Beach Cove
Cuslett Beach
Harricott Pt
Harricott R
Harricott Harbour
Mussel Pond Pt
Cape Dog
Cape Broyle
Cape Broyle Harbour
Cape Broyle Head
Brigus South
Cove Pond
Penstock
Bay Bulls
Bay Bulls Harbour
Bull Hd
South Hd
Witless Bay
Witless Bay Pt
Gull I
Mobile
Mobile Fish Pd
Mobile Bird Pond
Tors Cove
Burnt Cove
Bauline East
Bauline Pt
Bauline Line Pond
Mount Carmel Pond
Scotchtock
Bridge House
Franks Pd
Little Harbour
Little Harbour Pd
Harricott Pt
Harricott R
Harricott Harbour
Colinet R
Colinet Harbour
Colinet Island
Colinet Passage
Shoal Bay
Mall Bay
Beach Cove
Cuslett Beach
Double Road Pt
St Mary's Hr

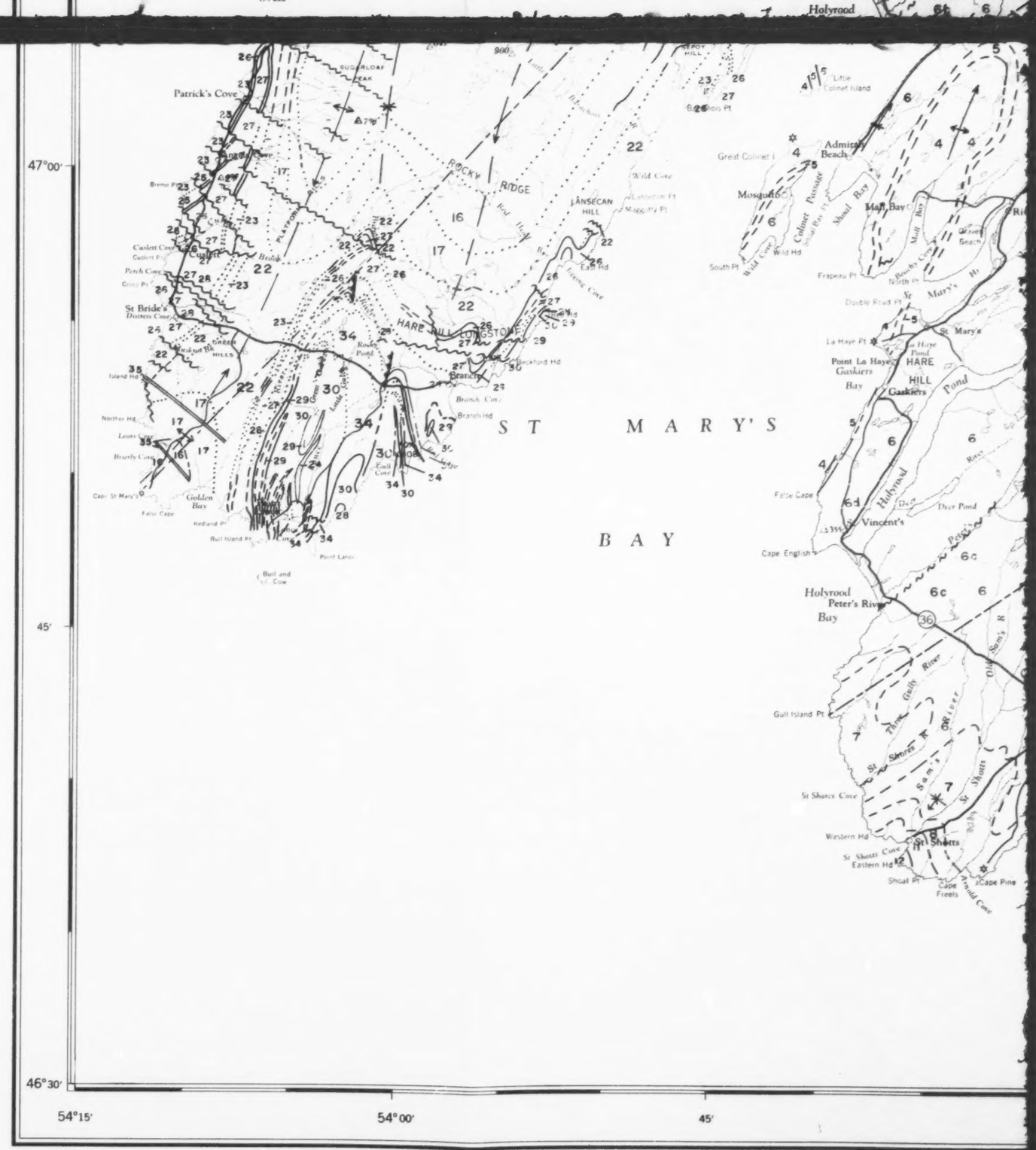
A. KING

1984
MAP 2

Scale 1:250,000

Miles 4 0 4 8 12 Miles

Kilometres 6 0 6 12 18 Kilometres


47°00′
45′
46°30′
54°15′
54°00′
45′
Patrick's Cove
Brene Pt
Caslett Cove
Caslett Pt
Perch Cove
Cove Pt
St Bride's
Distress Cove
Island Hd
Northern Hd
Briefly Cove
Cape St Mary's
False Cape
Golden Bay
Kedland Pt
Bull Island Pt
Bull and Cow
Point Lance
Gull Cove
Branch
Branch Cove
Branch Hd
Rocky Pond
Gull Pond
Gull Island Pond
Gull Island Pt
Western Hd
St Shotts
St Shotts Cove
Eastern Hd
Shoal Pt
Cape Freels
Arnold Cove
Cape Pine
St Shanes Cove
St Shanes Pt
Three Gully River
Old Shanes River
St Shanes River
Sam's River
Old Sam's River
Holyrood
Peter's River
Bay
St Vincent's
Cape English
Deer Pond
Gaskiers
Point La Haye
La Haye Pt
La Haye Pond
Gaskiers Bay
HARE HILL
LONGSTONE
ROCKY RIDGE
JANSECAN HILL
Great Colinet I
Little Colinet Island
Colinet Passage
Admiral's Beach
Mosquito
Mall Bay
Frapeau Pt
Double Road Pt
St Mary's
Wild Cove
Wild Hd
South Pt
Eastern Hd
Mistaken Pt
Mistaken Pond
Mistaken Pt
Cape Race
Cape Race
Cape Pine
Cape Pine
Cape Race
Cape Race
Cape Pine
Cape Pine
Cape Race
Cape Race
Cape Pine
Cape Pine

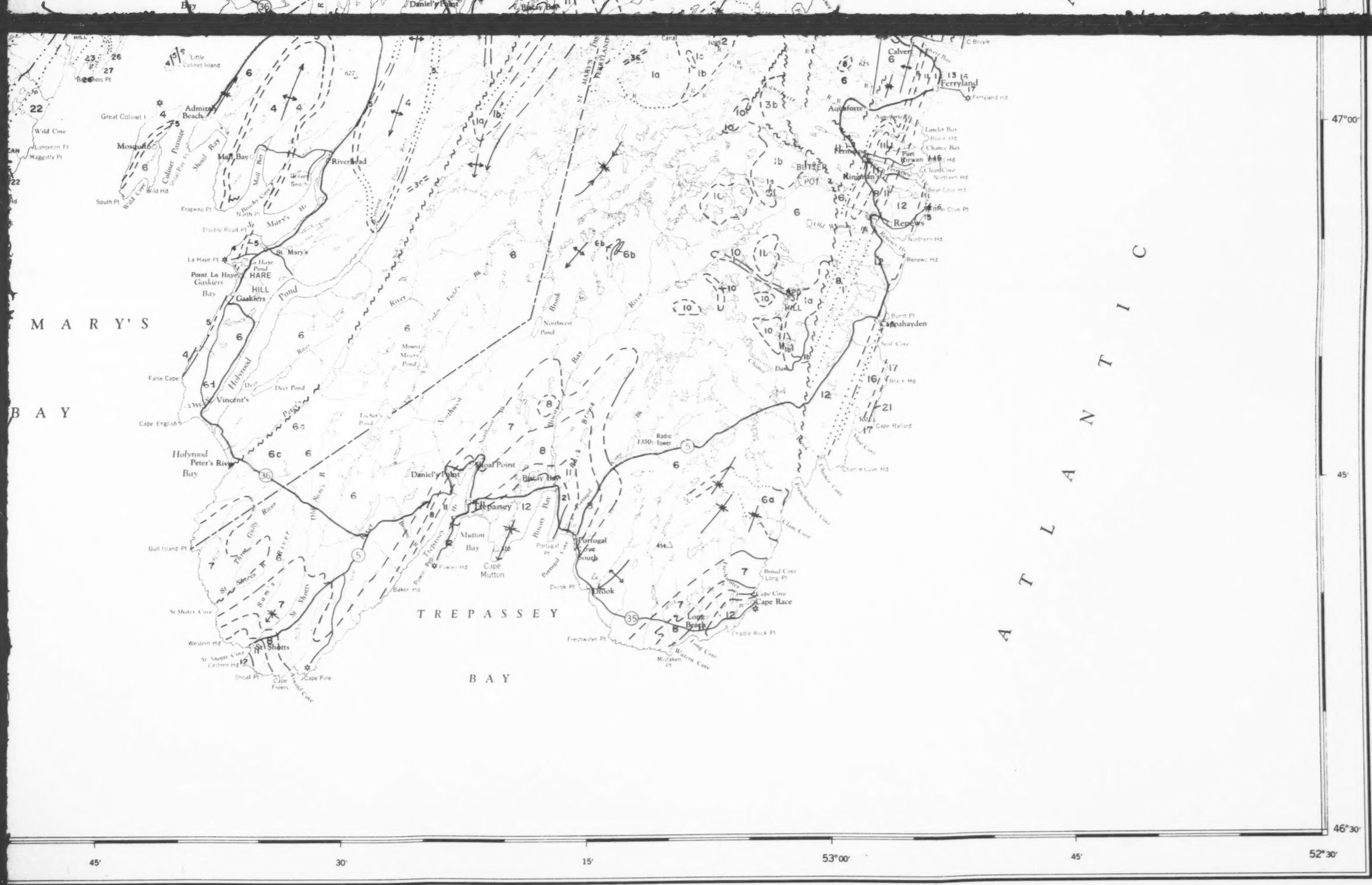
ST MARY'S BAY

TREPASSEY BAY

ATLANTIC

Patrick's Cove
Sugarloaf Peak
Rocky Ridge
Lansecan Hill
Hare Hill
Longstone
St Bride's
Golden Bay
Point Lance
Bull and Cow
Admiral Beach
Mosquito
Mall Bay
Riverhead
St Mary's
Point La Haye
Gaskiers
Gaskiers Bay
Pond Hill
Holyrood
Peter's River
Bay
St Vincent's
Cape English
Daniel's Point
Signal Point
Bacalay Bay
Trepassey
Mutton Bay
Cape Mutton
Fowles Hd
Portugal Cove South
Drook
Cape Race
Long Beach
Ferryland
Aquaforte
Calvert
Kinsman's
Renews
Cape Broyle
Chance Cove Hd
Cape Ballard
Radio Tower
Gull Island Pt
St Shotts
Cape Pine
Cape Freels
Western Hd
Eastern Hd
Snug Pt
Baker Hd
Drook Pt
Freshwater Pt
Cripple Rock Pt
Western Cove
Broad Cove Long Pt
Clam Cove
Portugal Cove
Portugal Pt
Biscay Bay
Northwest Pond
Mount Misery Pond
Deer Pond
Isher's Pond
Long Pond
Holyrood Pond
Gaskiers River
Salmonier River
Three Gulls River
St Shotts River
Colinet River
Mosquito River
Mall Bay Brook
Northwest Brook
Portugal Cove Brook
Freshwater Brook
Long Cove
Clam Cove
Frenchman's Cove
Chance Cove
Broad Cove
Cape Race
Cape Broyle
Ferryland
Aquaforte
Calvert
Kinsman's
Renews
Cape Broyle Hd
Ferryland Hd
Aquaforte Hd
Lawlor Bay
Black Hd
Chance Bay
Port Kirwan
Calvert Hd
Kinsman's Cove
Northern Hd
Renews Hd
Renews Cove Pt
Burnt Pt
Spahayden
Bird Cove
Black Hd
Cape Ballard
Chance Cove Hd
Broad Cove Pt
Long Cove
Cape Race
Long Beach
Cripple Rock Pt
Western Cove
Freshwater Pt
Drook Pt
Portugal Cove South
Portugal Pt
Biscay Bay
Trepassey
Mutton Bay
Cape Mutton
Fowles Hd
Baker Hd
Gull Island Pt
St Shotts
Cape Pine
Cape Freels
Western Hd
Eastern Hd
Snug Pt
St Shotts Cove
St Shotts Cove Eastern Hd
St Shotts Cove
Golden Bay
Point Lance
Bull and Cow
Patrick's Cove
Sugarloaf Peak
Rocky Ridge
Lansecan Hill
Hare Hill
Longstone
St Bride's
Admiral Beach
Mosquito
Mall Bay
Riverhead
St Mary's
Point La Haye
Gaskiers
Gaskiers Bay
Pond Hill
Holyrood
Peter's River
Bay
St Vincent's
Cape English
Daniel's Point
Signal Point
Bacalay Bay
Trepassey
Mutton Bay
Cape Mutton
Fowles Hd
Portugal Cove South
Drook
Cape Race
Long Beach
Ferryland
Aquaforte
Calvert
Kinsman's
Renews
Cape Broyle
Chance Cove Hd
Cape Ballard
Radio Tower
Gull Island Pt
St Shotts
Cape Pine
Cape Freels
Western Hd
Eastern Hd
Snug Pt
Baker Hd
Drook Pt
Freshwater Pt
Cripple Rock Pt
Western Cove
Broad Cove Long Pt
Clam Cove
Frenchman's Cove
Chance Cove
Broad Cove
Cape Race
Cape Broyle
Ferryland
Aquaforte
Calvert
Kinsman's
Renews
Cape Broyle Hd
Ferryland Hd
Aquaforte Hd
Lawlor Bay
Black Hd
Chance Bay
Port Kirwan
Calvert Hd
Kinsman's Cove
Northern Hd
Renews Hd
Renews Cove Pt
Burnt Pt
Spahayden
Bird Cove
Black Hd
Cape Ballard
Chance Cove Hd
Broad Cove Pt
Long Cove
Cape Race
Long Beach
Cripple Rock Pt
Western Cove
Freshwater Pt
Drook Pt
Portugal Cove South
Portugal Pt
Biscay Bay
Trepassey
Mutton Bay
Cape Mutton
Fowles Hd
Baker Hd
Gull Island Pt
St Shotts
Cape Pine
Cape Freels
Western Hd
Eastern Hd
Snug Pt
St Shotts Cove
St Shotts Cove Eastern Hd
St Shotts Cove
Golden Bay
Point Lance
Bull and Cow

54°00′ 45′ 30′ 15′ 53°00′ 45′


MARY'S
BAY
TREPASSEY
BAY
ATLANTIC
Admirals Beach
Great Colinet I
Little Colinet Island
Colinet Passage
Mosquito
Mall Bay
Riverhead
Frapeau Pt
St Mary's
La Haye Pt
Point La Haye
Gaskiers
HARE HILL
Gaskiers
La Haye Pond
Pond
Holyrood
Peter's River
Bay
False Cape
Vincent's
Cape English
Deer Pond
Gull Island Pt
St Shotts
Cape Pine
Cape Freels
Shoal Point
Daniel's Point
Bluesky Bay
Trepassey
Mutton Bay
Cape Mutton
Portugal Cove South
Portugal Pt
Drook
Drook Pt
Baker Hd
Western Hd
Eastern Hd
Shoal Pt
Mosquito Hd
Aquaforte
Ferryland
Calvert
Ferryland Hd
Kinsman
Renews
Renews Hd
Spahayden
Cape Ballard
Radio Tower
1350
Long Beach
Cape Race
Cape Cove
Broad Cove
Long Pt
Cripple Rock Pt
Mistaken Pt
Western Cove
Long Cove
Freshwater
Chance Cove Hd
Clam Cove
Frenchman's Cove
Black Hd
Burnt Pt
Seal Cove
Northern Hd
Bear Cove Hd
Port Kirwan
Lancey Bay
Chance Bay
Northwest Pond
Mount Misery Pond
Tucker's Pond
Deer Pond
Mall Bay
Shoal Bay
Colinet River
Gaskiers River
Three Gulch River
Sam's River
St Shotts River
Salmonier River
Northwest Brook
Northwest River
Trepassey Bay
Biscay Bay
Portugal Cove
Freshwater
Long Cove
Arnold Cove
Wild Cove
Lancaster Pt
Maggotty Pt
Wild Hd
South Pt
Double Road Pt
Mall Bay Hr
Mall Bay Cove
Gravel Beach
Shoal Bay Pt
Colinet Hr
Renews Hr
Old Woman
Northern Hd
Renews Hd
Burnt Pt
Seal Cove
Black Hd
Cape Ballard
Chance Cove Hd
Clam Cove
Frenchman's Cove
Broad Cove
Long Pt
Cape Cove
Cape Race
Cripple Rock Pt
Mistaken Pt
Western Cove
Long Cove
Freshwater
Drook Pt
Portugal Pt
Portugal Cove South
Baker Hd
Mutton Bay
Cape Mutton
Shoal Point
Daniel's Point
Bluesky Bay
Trepassey
Gull Island Pt
Shoal Pt
Cape Freels
Cape Pine
Arnold Cove
Western Hd
Eastern Hd
St Shotts
St Shotts Cove
St Shores Cove
Holyrood
Peter's River
Bay
False Cape
Vincent's
Cape English
Deer Pond
Mount Misery Pond
Tucker's Pond
Northwest Pond

BEDROCK HYDROSTRATIGRAPHIC UNITS

BEDROCK HYDROSTRATIGRAPHIC UNIT	WELL YIELD L/min./(gpm) MEAN	WELL YIELD L/min./(gpm) RANGE	WELL DEPTH m/(feet) MEAN	WELL DEPTH m/(feet) RANGE
UNIT A MODERATE YIELD Harbour Main Group, Holyrood Granite (Volcanics, Sedimentary, Intrusive granitic rocks) (1a,1b,1c,1d,2,3)*	25.2 (5.5)	1.1-136.5 (0.25-30.)	43.7 (143.3)	7.0-154.5 (23.-507.)
UNIT B LOW TO MODERATE YIELD Conception, Dildo Groups (Siliceous sandstone, shale, siltstone, tuff, tillite, volcaniclastics conglomerate) (4,5,6,7,8,22,23,24)*	20.1 (4.5)	0.6-136.5 (0.13-30.)	51.7 (169.5)	9.8-152.4 (32.2-500)
UNIT C MODERATE TO HIGH YIELD Signal Hill Group (Breccia, conglomerate, sandstone, siltstone, shale, tuff) (15,16,17,18,19,20)*	43.0 (9.5)	1.1-273. (0.25-60.)	49.7 (163.1)	12.2-111.3 (40.-365.2)
UNIT D MODERATE YIELD St. John's Group, Random Group, Bonavista, Smith Point, Brigus, Chamberlains Brook, Manuels River, Elliot Cove Formations. (Shale, slate, limestone, quartzite, conglomerate, arkose, siltstone sandstone) (11,12,13,26,27,28,30)*	27.4 (6.0)	1.1-364 (0.25-80)	47.7 (156.5)	7.0-121.9 (23.-400)
UNIT E HIGH YIELD Wabana and Bell Island	73.5	6.8-273	77.2	21.3-201.2

BEDROCK HYDROGEOLOGY

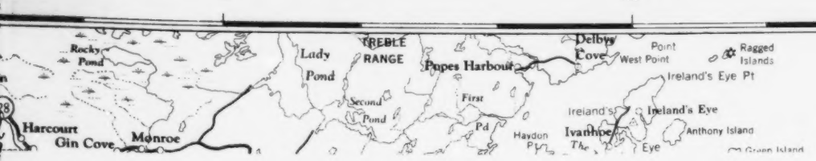
AVALON PENINSULA AREA

1984
MAP 3

Scale 1: 250,000

5 0 5 10 15 20 25
kilometres

FRACFLOW CONSULTANTS INC.



STRATIGRAPHIC UNITS

WELL YIELD /min./(gpm)		WELL DEPTH m/(feet)	
AN	RANGE	MEAN	RANGE
2	1.1-136.5	43.7	7.0-154.5
.5)	(0.25-30.)	(143.3)	(23.-507.)
.1	0.6-136.5	51.7	9.8-152.4
.5)	(0.13-30.)	(169.5)	(32.2-500)
0	1.1-273.	49.7	12.2-111.3
5)	(0.25-60.)	(163.1)	(40.-365.2)
4	1.1-364	47.7	7.0-121.9
0)	(0.25-80)	(156.5)	(23.-400)
	6.8-273	77.2	21.3-201.2

BEDROCK HYDROGEOLOGY

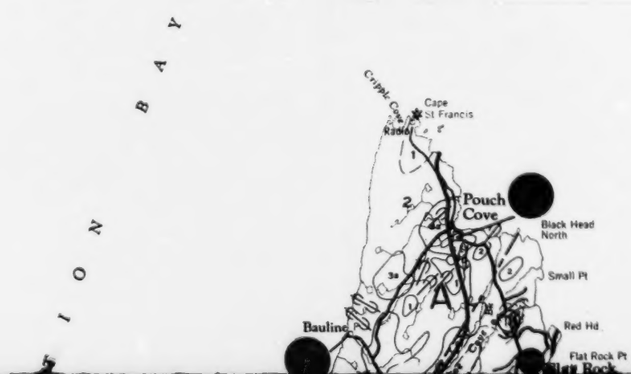
AVALON PENINSULA AREA

1984
MAP 3

Scale 1: 250,000

5 0 5 10 15 20 25
kilometres

FRACFLOW CONSULTANTS INC.



shale, tuff) (15,16,17,18,19,20)*				
UNIT D MODERATE YIELD St. John's Group, Random Group, Bonavista, Smith Point, Brigus, Chamberlains Brook, Manuels River, Elliot Cove Formations. (Shale, slate, limestone, quartzite, conglomerate, arkose, siltstone sandstone) (11,12,13,26,27,28,30)*	27.4 (6.0)	1.1-364 (0.25-80)	47.7 (156.5)	7.0-121.9 (23.-400)
UNIT E HIGH YIELD Wabana and Bell Island Groups (Sandstone, siltstone, shale) (32,33)	73.5 (16.2)	6.8-273 (1.5-60)	77.2 (253.3)	21.3-201.2 (70.-660.)
NC (Not Classified)*				

* Numbers refer to bedrock geology map units.

NUMBER OF WELLS LISTED PER COMMUNITY

●1-4 ●5-10 ●11-12 ●21-40 ●>40

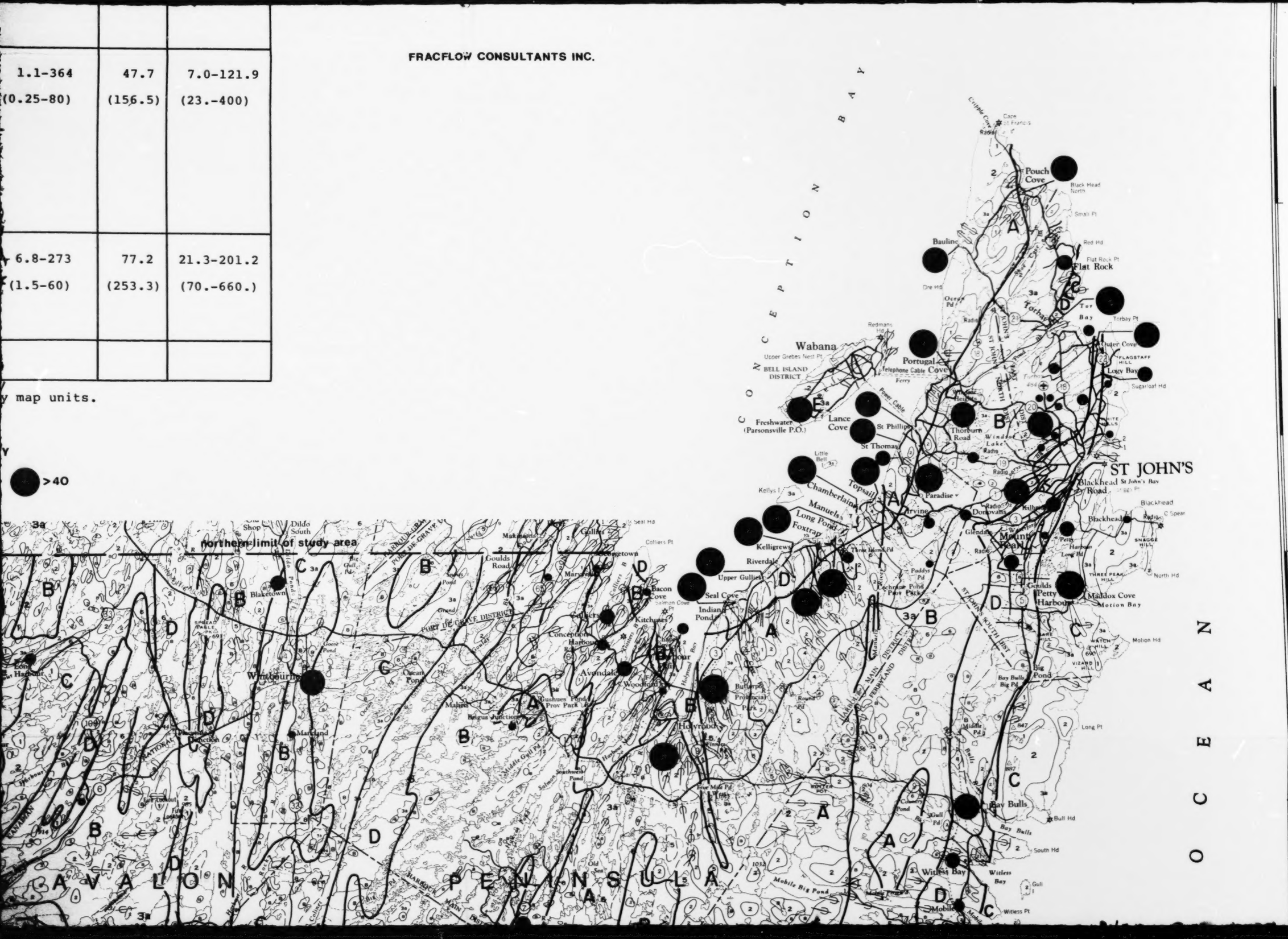
FRACFLOW CONSULTANTS INC.

1.1-364 (0.25-80)	47.7 (156.5)	7.0-121.9 (23.-400)
6.8-273 (1.5-60)	77.2 (253.3)	21.3-201.2 (70.-660.)

y map units.

y

>40



PLACENTIA

BAY

AVALON PENINSULA

ST MARY'S BAY

47°00'

Placentia

Argentia

Dunville

Jerseyside

Freshwater

Point Verde

Southeast Placentia

Little Barasway

Great Barasway

Ship Cove

Gooseberry Cove

Patrick's Cove

Angels Cove

Cuslett

St Bride's

Branch

Golden Bay

Point Lance

Fox Harbour

Ship Harbour

Red Island

Placentia Junction

Marsland

Colinet

Harricott

St Catherine's

Mount Carmel

Forest Field

New Bridge

Mitchells Brook

St Joseph's

North Harbour

Point La Haye

Gaskiers

Mosquito

Admirals Beach

Mall Bay

Riverhead

O'Donnells

Mussel Pond

Holyrood

Cape English

St Vincent's

False Cape

Bellgus Junction

Gushues Pond Prov Park

Holyrood

Aquaforte

Kingman's Cove

Renews

Cappahayden

Cape Broyle

Cape Ballard

Placentia West

Placentia East

Placentia Sound

Argentia Hr

Long Harbour

Ship Harbour

Placentia Road

Point Verde

Southeast Placentia

Little Barasway

Great Barasway

Ship Cove

Gooseberry Cove

Patrick's Cove

Angels Cove

Cuslett

St Bride's

Branch

Golden Bay

Point Lance

Lance Cove

Red Cove

Branch Cove

Gull Cove

Fox Harbour

Ship Harbour

Placentia Junction

Marsland

Colinet

Harricott

St Catherine's

Mount Carmel

Forest Field

New Bridge

Mitchells Brook

St Joseph's

North Harbour

Point La Haye

Gaskiers

Mosquito

Admirals Beach

Mall Bay

Riverhead

O'Donnells

Mussel Pond

Holyrood

Cape English

St Vincent's

False Cape

Bellgus Junction

Gushues Pond Prov Park

Holyrood

Aquaforte

Kingman's Cove

Renews

Cappahayden

Cape Broyle

Cape Ballard

Placentia West

Placentia East

Placentia Sound

Argentia Hr

Long Harbour

Ship Harbour

Placentia Road

Point Verde

Southeast Placentia

Little Barasway

Great Barasway

Ship Cove

Gooseberry Cove

Patrick's Cove

Angels Cove

Cuslett

St Bride's

Branch

Golden Bay

Point Lance

Lance Cove

Red Cove

Branch Cove

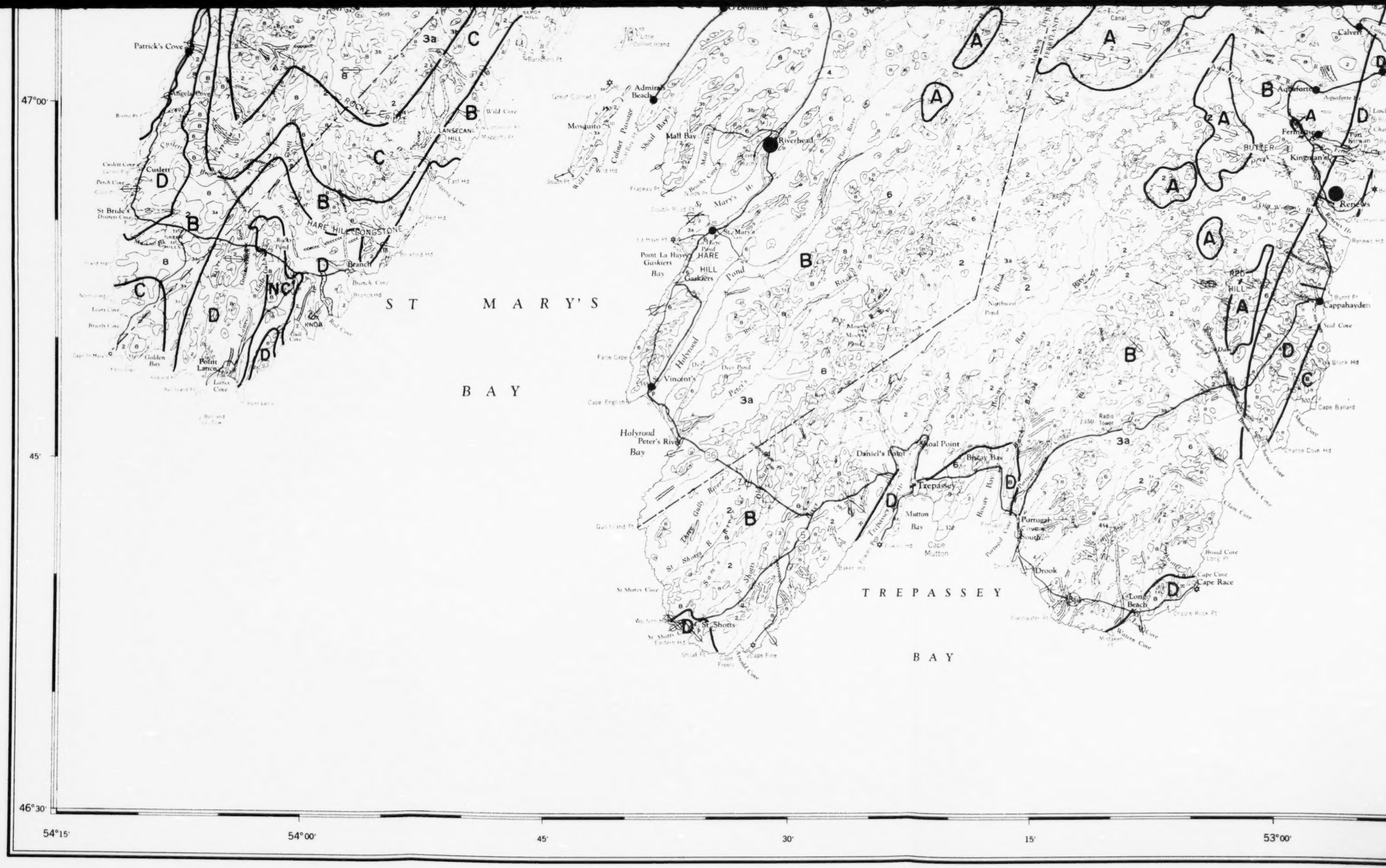
Gull Cove

AVALON PENINSULA

MARY'S BAY

OCEANIC

Bay Bulls
Witless Bay
Mobile
Tors Cove
Burnt Cove
Bauline East
Pouch Cove
Flatrock
Torbay
Logy Bay
Middle Cove
Outer Cove
Long Pond
Portugal Cove
Petty Harbour
Maddox Cove
Bauline
Witless Bay Line
Mobile Big Pond
Paradise Pond
Butler Pd
Mount Carmel Pond
Saunders Ponds
Southwest Pond
Middle Gull Pd
Southwest Pond
Bushues' Pond
Prov Park
Butterpot Provincial Park
Woodford's
Holyrood
Salmonier
Salmonier Pond
Harbour Main
Main Pond
Old Sea
Mobile Pond
Middle Pd
Big Pd
Long Pt
Bull Hd
South Hd
Witless Bay
Witless Pt
Tinker Pt
Great Pd
Mobile Pt
Tors Cove Pd
Burnt Cove Pd
Bauline Pd
Bauline Line
Pouch Cove Pd
Flatrock Pd
Torbay Pd
Logy Bay Pd
Middle Cove Pd
Outer Cove Pd
Long Pond
Portugal Cove Pd
Petty Harbour Pd
Maddox Cove Pd



47°00'
45'
46°30'
54°15'
54°00'
45'
30'
15'
53°00'

MARY'S BAY

TREPASSEY BAY

ATLANTIC

Little Colinet Island
Barachois Pt
Great Colinet I
Admirals Beach
Wild Cove
Lansecon Pt
Maggotty Pt
Mosquito
Colinet Passage
Shoal Bays
Mall Bay
Riverhead
South Pt
Wild Cove
Wild Hd
Frapeau Pt
North Pt
Beaches Cove
St Mary's Hr
Double Road Ft
St Mary's
La Haye Pt
Point La Haye
Gaskiers Bay
HARE
HILL
Gaskiers
Pond
False Cape
Holyrood
Deer
Deer Pond
Peter's
Vincent's
Cape English
Holyrood
Peter's River
Bay
Gull Island Pt
Gull
Shoal
Peter's River
St Shores
Sam's
St Shores Cove
St Shotts
Western Hd
St Shotts
Eastern Hd
Shoal Pt
Cape Pine
Cape Freels
Arnold Cove
Daniel's Point
Shoal Point
Bristy Bay
Trepassey
Mutton Bay
Cape Mutton
Portugal Cove South
Drook
Drook Pt
Freshwater Pt
Long Beach
Long Cove
Western Cove
Cape Race
Broad Cove
Long Pt
Cape Cove
Cripple Rock Pt
Radio Tower
1350
Canal
Calvert
Ferryland
Aquaforte
Fermeuse
Kingman's
BUTTER POT
Renews
Northern Hd
Renews Hr
Renews Hd
Cappahayden
Burnt Pt
Seal Cove
Chance Bay
Port Kirwan
Lauder Bay
Bear Cove Pt
Northern Hd
Calvert Bay
Broyle
Ferryland Hd
Aquaforte Hr
Fermeuse Hd
Bear Cove Hd
Renews Hd
Cape Ballard
Chance Cove Hd
Bauline Cove
Frenchmen's Cove
Clam Cove
Bauline Cove Hd
RPD HILL
Northwest Pond
Mount Misery
Misery Pond
Northwest Pond
Bay
Brook
Portugal Cove
Portugal Pt
Flowers Hd
Eastern Hd
Mutton Hill
326
434
1350
3a
6x
36
RPD

45'
30'
15'
53°00'
45'
52°30'
47°00'
45'
46°30'

Well Name	Location	Bedrock Unit	Well Type[3]	Well Depth (m)	Date Sampled D/M/Y	Tot. Diss. Solids (mg/L)	Specific Conduct. (mmhos/cm)	pH (units)	Hardness (mg/L) ($CaCO_3$)	Alkalinity (mg/L) ($CaCO_3$)	CATIONS									
											Calcium (mg/L)	Magnes. (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Iron (mg/L)	Mangan. (mg/L)	Copper (mg/L)	Zinc (mg/L)	Lead (mg/L)	Cadm (mg
Municipal No.3	Admiral's Beach[1]	Drook Fmn.	B	12.9	10/02/80	135	256.1	8.30	112.9	94.1	24.8	12.36	10.8	-	<0.01	0.046	-	-	<0.01	
Municipal No.5	Admiral's Beach[1]	"	B	19.4	22/02/80	143	252.7	8.26	118.8	101.1	31.1	9.94	10.50	-	0.036	0.068	-	-	-	
Domestic-00041	Bauline	Harbour Main	B	36.	15/06/79	86	127.0	6.46	46.4	42.6	12.8	3.27	6.95	0.808	0.443	0.025	-	-	-	
Domestic-00049	Bauline	Group/Holyrood	B	6.	15/06/79	1128	-	6.85	331.4	69.8	100.7	19.43	-	-	-	-	-	-	-	
Domestic-00050	Bauline	Granite	B	63.	15/06/79	1077	204.9	6.31	139.9	28.6	46.3	5.59	353.1	7.563	0.296	0.394	-	-	-	
Municipal No.3	Bell Island (Wabana)	Bell Island	B	48.	09/12/76	-	442.6	7.96	155.3	145.4	46.5	9.40	-	-	0.067	0.238	<0.01	0.021	-	0.
Municipal-Davidson Ave.	Bell Island (Wabana)	and	B	103.3	09/12/76	-	373.7	7.80	156.5	129.8	51.9	6.28	-	-	0.438	0.158	<0.01	0.018	-	0.
Municipal-Woods Ave.	Bell Island (Wabana)	Wabana Groups	B	165.5	09/12/76	-	398.8	8.42	111.1	121.8	33.6	6.55	-	-	0.129	0.043	<0.01	0.071	-	<0.
Municipal-Downing St.	Bell Island (Wabana)		B	64.	09/12/76	-	449.2	8.16	103.2	116.2	31.0	6.15	-	-	0.079	0.129	<0.01	0.029	-	<0.
Municipal	Bell Island (Wabana)		B	121.9	09/12/76	-	413.1	8.86	91.7	141.0	13.39	1.63	-	-	0.112	0.031	<0.01	<0.01	-	<0.
Municipal-Main St.	Bell Island (Wabana)		B	190.5	09/12/76	-	367.4	7.86	113.5	146.2	38.01	4.23	-	-	0.523	0.117	<0.01	0.021	-	<0.
Municipal-Railroad St.	Bell Island (Wabana)		B	64.	09/12/76	-	362.1	7.96	138.1	115.4	44.09	5.60	-	-	2.066	0.650	<0.01	0.033	-	<0.
Municipal-East No. 1	Bell Island (Wabana)	"	B	24.4	09/12/76	-	416.9	6.28	109.3	52.0	32.79	6.55	-	-	0.135	0.337	0.100	0.037	-	0.
Municipal- Bridal Ave.	Bell Island (Wabana)		B	-	09/12/76	-	458.5	7.70	163.2	118.4	55.68	5.56	-	-	0.088	0.595	<0.01	0.021	-	<0.
Domestic	Bell Island		B	27.4	03/11/80	203	380.	7.66	129.2	100.	38.98	7.39	23.85	-	0.48	0.33	0.02	0.20	-	<0.
Municipal	Blaketown[1]	Quidi Vidi Fmn.	B	69.	10/01/83	220	190	8.50	17.9	86.0	5.10	1.02	29.00	-	0.28	0.02	-	-	<0.01	
Municipal	Calvert[1]	Drook-Mistaken Pt.	B	36.5	19/05/82	-	50	4.58	4.9	<1	0.69	0.58	-	-	0.38	0.05	0.02	<0.01	-	<0.
Domestic (?)	Calvert		?	-	22/05/81	-	60	6.20	8.9	2	1.53	1.15	-	-	0.14	0.03	<0.01	<0.01	-	<0.
Domestic (?)	Calvert		?	-	?	-	80	4.63	10.1	<1	1.67	1.28	-	-	0.21	0.14	<0.01	<0.01	-	<0.
Domestic (1921)	Chamberlains	?	?	-	12/07/79	908	-	8.96	48.4	111.8	17.02	1.42	-	-	-	-	-	-	-	
Domestic (1920)	Chamberlains	?	?	-	12/07/79	144	171.7	7.20	61.7	45.6	18.27	3.74	10.07	0.715	0.034	0.335	-	-	-	
Domestic-00347	Flat Rock	Drook Fmn. ?	?	-	24/08/81	269	-	8.11	108.7	64	30.4	7.96	-	-	-	-	-	-	-	
Domestic-00209	Foxtrap	Drook-Mistaken Pt.	B	17.4	08/08/80	155	203.7	7.10	77.3	71.0	25.05	2.97	9.68	0.74	0.60	0.790	-	-	-	
Domestic-00333	Harbour Main	Drook Fmn.	B	31.	08/08/80	140	80.1	7.28	74.5	76.7	26.80	1.83	9.43	-	0.06	<0.01	-	-	-	
Domestic-00337	Harbour Main	Gaskiers Fmn.	B	18.6	08/08/80	277	-	6.78	84.2	85.4	28.10	3.42	-	-	-	-	-	-	-	
Domestic-00319	Holyrood	Drook Fmn.	B	14.4	08/08/80	111	308.5	7.95	67.9	86.6	24.44	1.65	39.81	0.89	0.07	<0.01	-	-	-	
Domestic-00322	Holyrood	Harbour Main (lc)	B	-	08/08/80	86	106.4	6.67	31.6	28.6	10.22	1.43	7.75	0.42	0.08	<0.01	-	-	-	
Domestic-00327	Holyrood	Harbour Main (lb/c)	?	-	08/08/80	573	781.4	7.16	237.5	154.1	84.24	5.64	61.36	1.16	1.03	1.17	-	-	-	
Domestic-00292	Indian Pond	Bonavista, Smith Pt.	B	72.	08/08/80	38	-	7.22	65.4	26.1	22.08	2.49	-	-	-	-	-	-	-	
Institutional-00298	Indian Pond	Harbour Main(la)	B	34.5	08/08/80	83	281.2	6.99	65.9	58.6	23.23	1.90	27.63	1.39	0.05	0.01	-	-	-	
Domestic-00309	Indian Pond	Harbour Main(la)	B	18.	08/08/80	70	159.2	7.12	58.8	50.7	18.87	2.31	6.64	0.70	0.10	0.01	-	-	-	
Domestic-00407A	Logy Bay	Cuckold Fmn.	B	16.5	24/08/81	158	200	6.55	32.4	23	8.57	2.65	17.5	1.02	0.03	0.02	-	-	-	
Domestic-00427	Logy Bay	Quidi Vidi Fmn.	?	-	24/08/81	118	160	6.58	48.6	39	13.1	3.49	11.7	1.20	0.45	0.41	-	-	-	
Municipal-1	O'Donnells[1]	Drook Fmn.	B	93.	05/01/81	161	320	8.28	49.8	81.7	13.39	3.45	48.2	-	1.16	0.05	-	-	<0.01	
Domestic-00051	Portugal Cove	Harbour Main, Gaskiers Fmn.	B	154.	29/06/79	155	251.6	8.37	57.1	70.8	20.03	0.84	29.72	0.430	0.014	0.087	-	-	-	
Domestic-00060	Portugal Cove	Drook Fmn.	?	-	29/06/79	78	114.1	6.4	22.0	14.2	6.51	1.36	10.43	0.822	0.047	0.025	-	-	-	
Domestic-00076	Portugal Cove	Harbour Main, Mall Bay, Drook Fmn.	B	50.	29/06/79	275	423.3	9.39	14.6	48.2	5.65	0.08	77.75	0.848	0.043	0.01	-	-	-	
Domestic-00078	Portugal Cove	"	B	-	29/06/79	44	75.8	5.78	8.5	3.6	1.81	0.92	9.73	0.451	0.053	0.015	-	-	-	
Domestic-00063	Portugal Cove	"	B	72.	29/06/79	169	-	8.25	91.2	93.4	31.46	3.08	-	-	-	-	-	-	-	
Domestic-00068	Portugal Cove	"	B	73.8	29/06/79	156	-	8.16	56.2	73.6	21.15	0.82	-	-	-	-	-	-	-	
Domestic #4	Pouch Cove	Drook Fmn.	B	60.	13/06/79	473	570	7.75	388.8	103	142.6	7.94	23.24	0.938	0.025	<0.01	-	-	-	
Domestic #24	Pouch Cove	"	B	92.5	09/06/79	141	272	7.62	76.8	87.6	26.9	2.33	21.17	0.846	0.035	0.031	-	-	-	
Domestic 25	Pouch Cove	"	B	51.	09/06/79	251	-	5.70	51.2	13.6	14.8	3.46	-	-	-	-	-	-	-	
Municipal-Capp. North	Renews-Cappahayden[1]	?	B	62.2	19/08/83	-	-	-	-	-	-	-	-	-	1.24	0.51	-	-	-	
Domestic-00297	Seal Cove	Chamberlains Brook	B	25.2	08/08/80	201	241.4	6.44	53.5	16.6	11.31	6.06	21.69	1.10	0.17	0.01	-	-	-	
Domestic-00353	Shoe Cove	Drook Fmn.	B	-	24/08/81	78	120	6.93	23.2	13	5.97	1.99	11.3	0.57	0.05	<0.01	-	-	-	
Domestic #12	St. Phillips	Harbour Main Group	?	-	10/07/79	64	1181.8	7.13	332.0	50.2	128.63	2.48	80.28	0.590	0.300	0.020	-	0.058	-	
Domestic (96)	Thorburn Road	Ablation Moraine	O	-	21/01/80	-	94.1	5.24	14.8	1	3.96	1.07	6.21	-	0.052	0.232	0.01	0.015	-	
Domestic (97)	Thorburn Road	"	O	-	21/01/80	-	87.3	5.89	19.0	11.3	4.97	1.36	7.77	-	0.419	0.125	0.174	0.191	-	
Domestic (98)	Thorburn Road	"	O	-	21/01/80	-	67.0	6.01	14.0	3.0	2.53	1.43	6.58	-	0.425	0.583	0.014	0.432	-	
Domestic (99)	Thorburn Road	"	O	-	21/01/80	-	134.8	5.69	10.5	2.4	2.47	0.99	48.3	-	0.077	0.087	0.261	0.128	-	
Domestic-00365	Torbay	St. John's or	B	97.5	24/08/81	206	350	8.01	119.3	123	40.1	4.64	10.3	1.15	0.04	0.01	-	-	-	
Domestic-00383	Torbay	Signal Hill Groups	B	30.5	24/08/81	142	-	6.76	42.4	25	14.3	1.62	-	-	-	-	-	-	-	
Domestic-00413	Torbay	(12,13,14,or16)	B	-	24/08/81	209	370	6.47	48.4	27	14.6	2.83	43.0	1.84	0.02	0.12	-	-	-	
Observation-NPB #1	Torbay[2]	Stoney Till	O	6.1	23/04/81	54	70	5.71	11.4	3	2.3	1.38	7.73	0.60	0.01	0.04	0.06	<0.01	<0.01	<0.
Observation-NPB #2	Torbay[2]	"	O	4.0	23/04/81	54	80	5.74	12.1	7	2.4	1.45	9.39	0.42	<0.01	0.02	0.02	<0.01	<0.01	<0.
Observation-NPB #3	Torbay[2]	"	O	6.2	23/04/81	48	60	5.39	11.8	3	3.1	0.96	5.58	0.65	<0.01	0.03	0.07	0.01	<0.01	<0.
Observation-NPB #4	Torbay[2]	"	O	3.8	23/04/81	186	300	4.60	50.6	<1	15.2	2.54	23.8	5.80	<0.01	1.19	0.48	0.20	<0.01	<0.
Observation-NPB #5	Torbay[2]	"	O	5.4	23/04/81	68	100	5.23	12.3	1	1.9	1.78	12.8	0.68	0.01	0.05	0.11	0.41	<0.01	<0.
Observation-Site E(Sh-)	Waterfd. River Basin[2]	Stoney Till	O																	

Date Sampled D/M/Y	Tot. Diss. Solids (mg/L)	Specific Conduct. (mmhos/cm)	pH (units)	Hardness (mg/L) ($CaCO_3$)	Alkalinity (mg/L) ($CaCO_3$)	CATIONS										ANIONS							Apparent Colour (TCU)	Turbid. (JTU)	COD (mg/L)
						Calcium (mg/L)	Magnes. (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Iron (mg/L)	Mangan. (mg/L)	Copper (mg/L)	Zinc (mg/L)	Lead (mg/L)	Cadmium (mg/L)	Chlor. (mg/L)	Sulf. (mg/L)	Nitrate N(mg/L)	Nitrite N(mg/L)	Kjeldahl N(mg/L)	Phos. (mg/L)	Fluor. (mg/L)			
/02/80	135	256.1	8.30	112.9	94.1	24.8	12.36	10.8	-	<0.01	0.046	-	-	<0.01	-	16	9	-	-	0.263	-	-	<5	0.43	-
/02/80	143	252.7	8.26	118.8	101.1	31.1	9.94	10.50	-	0.036	0.068	-	-	-	-	14	9	-	-	0.286	-	-	<5	0.33	-
/06/79	86	127.0	6.46	46.4	42.6	12.8	3.27	6.95	0.808	0.443	0.025	-	-	-	-	20	1	<0.005	-	-	-	-	-	-	-
/06/79	1128	-	6.85	331.4	69.8	100.7	19.43	-	-	-	-	-	-	-	-	423	-	-	-	-	-	-	-	-	-
/06/79	1077	204.9	6.31	139.9	28.6	46.3	5.59	353.1	7.563	0.296	0.394	-	-	-	-	593	29	4.683	-	-	-	-	-	-	-
/12/76	-	442.6	7.96	155.3	145.4	46.5	9.40	-	-	0.067	0.238	<0.01	0.021	-	0.01	-	-	0.551	-	0.125	0.070	-	7.5	0.16	3.36
/12/76	-	373.7	7.80	156.5	129.8	51.9	6.28	-	-	0.438	0.158	<0.01	0.018	-	0.01	-	-	0.056	-	0.440	0.071	-	10.	1.15	0.46
/12/76	-	398.8	8.42	111.1	121.8	33.6	6.55	-	-	0.129	0.043	<0.01	0.071	-	<0.01	-	-	0.026	-	0.331	0.077	-	<5	0.40	<0.2
/12/76	-	449.2	8.16	103.2	116.2	31.0	6.15	-	-	0.079	0.129	<0.01	0.029	-	<0.01	-	-	0.026	-	0.374	0.056	-	<5	0.16	7.07
/12/76	-	413.1	8.86	91.7	141.0	13.39	1.63	-	-	0.112	0.031	<0.01	<0.01	-	<0.01	-	-	0.021	-	0.470	0.108	-	5	0.40	<0.2
/12/76	-	367.4	7.86	113.5	146.2	38.01	4.23	-	-	0.523	0.117	<0.01	0.021	-	<0.01	-	-	0.008	-	0.174	0.066	-	15	0.60	<0.2
/12/76	-	362.1	7.96	138.1	115.4	44.09	5.60	-	-	2.066	0.650	<0.01	0.033	-	<0.01	-	-	0.055	-	0.075	0.122	-	10	0.75	8.62
/12/76	-	416.9	6.28	109.3	52.0	32.79	6.55	-	-	0.135	0.337	0.100	0.037	-	0.01	-	-	2.220	-	0.033	0.060	-	<5	0.40	2.19
/12/76	-	458.5	7.70	163.2	118.4	55.68	5.56	-	-	0.088	0.595	<0.01	0.021	-	<0.01	-	-	0.120	-	0.101	0.062	-	5	0.18	15.64
/11/80	203	380.	7.66	129.2	100.	38.98	7.39	23.85	-	0.48	0.33	0.02	0.20	-	<0.005	43	22	0.300	-	-	0.020	-	5	0.76	9.
/01/83	220	190	8.50	17.9	86.0	5.10	1.02	29.00	-	0.28	0.02	-	-	<0.01	-	9.49	-	<0.002	-	-	-	-	-	17	-
/05/82	-	50	4.58	4.9	<1	0.69	0.58	-	-	0.38	0.05	0.02	<0.01	-	<0.005	-	-	0.013	-	0.022	0.016	-	70	0.48	37
/05/81	-	60	6.20	8.9	2	1.53	1.15	-	-	0.14	0.03	<0.01	<0.01	-	<0.005	-	-	0.015	-	0.299	0.021	-	50	0.64	18
?	-	80	4.63	10.1	<1	1.67	1.28	-	-	0.21	0.14	<0.01	<0.01	-	<0.005	-	-	0.044	-	0.44	0.015	-	20	0.62	18
/07/79	908	-	8.96	48.4	111.8	17.02	1.42	-	-	-	-	-	-	-	-	302	-	-	-	-	-	-	-	-	-
/07/79	144	171.7	7.20	61.7	45.6	18.27	3.74	10.07	0.715	0.034	0.335	-	-	-	-	18	36	<0.005	0.002	-	-	-	-	-	-
/08/81	269	-	8.11	108.7	64	30.4	7.96	-	-	-	-	-	-	-	-	86	-	-	-	-	-	-	-	-	-
/08/80	155	203.7	7.10	77.3	71.0	25.05	2.97	9.68	0.74	0.60	0.790	-	-	-	-	15	16	<0.005	<0.005	-	-	-	-	-	-
/08/80	140	80.1	7.28	74.5	76.7	26.80	1.83	9.43	-	0.06	<0.01	-	-	-	-	12	10	0.686	<0.005	-	-	-	-	-	-
/08/80	277	-	6.78	84.2	85.4	28.10	3.42	-	-	-	-	-	-	-	-	64	-	-	-	-	-	-	-	-	-
/08/80	111	308.5	7.95	67.9	86.6	24.44	1.65	39.81	0.89	0.07	<0.01	-	-	-	-	35	12	0.017	<0.005	-	-	-	-	-	-
/08/80	86	106.4	6.67	31.6	28.6	10.22	1.43	7.75	0.42	0.08	<0.01	-	-	-	-	13	<5	0.413	<0.005	-	-	-	-	-	-
/08/80	573	781.4	7.16	237.5	154.1	84.24	5.64	61.36	1.16	1.03	1.17	-	-	-	-	132	20	0.026	<0.005	-	-	-	-	-	-
/08/80	38	-	7.22	65.4	26.1	22.08	2.49	-	-	-	-	-	-	-	-	27	-	-	-	-	-	-	-	-	-
/08/80	83	281.2	6.99	65.9	58.6	23.23	1.90	27.63	1.39	0.05	0.01	-	-	-	-	44	6	0.738	<0.005	-	-	-	-	-	-
/08/80	70	159.2	7.12	58.8	50.7	18.87	2.31	6.64	0.70	0.10	0.01	-	-	-	-	11	11	0.026	<0.005	-	-	-	-	-	-
/08/81	158	200	6.55	32.4	23	8.57	2.65	17.5	1.02	0.03	0.02	-	-	-	-	36	12	1.28	0.001	-	-	-	-	-	-
/08/81	118	160	6.58	48.6	39	13.1	3.49	11.7	1.20	0.45	0.41	-	-	-	-	20	8	0.252	0.001	-	-	-	-	-	-
/01/81	161	320	8.28	49.8	81.7	13.39	3.45	48.2	-	1.16	0.05	-	-	<0.01	-	1	18	0.336	-	-	-	-	5	4.4	-
/06/79	155	251.6	8.37	57.1	70.8	20.03	0.84	29.72	0.430	0.014	0.087	-	-	-	-	26	28	0.005	0.001	0.116	-	-	-	-	-
/06/79	78	114.1	6.4	22.0	14.2	6.51	1.36	10.43	0.822	0.047	0.025	-	-	-	-	25	12	0.578	<0.001	0.073	-	-	-	-	-
/06/79	275	423.3	9.39	14.6	48.2	5.65	0.08	77.75	0.848	0.043	0.01	-	-	-	-	27	215	0.012	0.002	0.091	-	-	-	-	-
/06/79	44	75.8	5.78	8.5	3.6	1.81	0.92	9.73	0.451	0.053	0.015	-	-	-	-	22	6	0.223	<0.001	0.138	-	-	-	-	-
/06/79	169	-	8.25	91.2	93.4	31.46	3.08	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-
/06/79	156	-	8.16	56.2	73.6	21.15	0.82	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-
/06/79	473	570	7.75	388.8	103	142.6	7.94	23.24	0.938	0.025	<0.01	-	-	-	-	82	27	7.06	-	-	-	-	-	-	-
/06/79	141	272	7.62	76.8	87.6	26.9	2.33	21.17	0.846	0.035	0.031	-	-	-	-	31	8	0.129	-	-	-	-	-	-	-
/06/79	251	-	5.70	51.2	13.6	14.8	3.46	-	-	-	-	-	-	-	-	81	-	-	-	-	-	-	-	-	-
/08/83	-	-	-	-	-	-	-	-	-	1.24	0.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-
/08/80	201	241.4	6.44	53.5	16.6	11.31	6.06	21.69	1.10	0.17	0.01	-	-	-	-	55	0.563	<0.005	-	-	-	-	-	-	-
/08/81	78	120	6.93	23.2	13	5.97	1.99	11.3	0.57	0.05	<0.01	-	-	-	-	20	0.405	0.002	-	-	-	-	-	-	-
/07/79	64	1181.8	7.13	332.0	50.2	128.63	2.48	80.28	0.590	0.300	0.020	-	0.058	-	-	284	237	0.021	<0.001	-	-	-	-	-	-
/01/80	-	91.1	5.24	14.8	1	3.96	1.07	6.21	-	0.052	0.232	0.01	0.015	-	-	10	11	2.57	-	0.311	0.062	-	5	0.50	11
/01/80	-	87.3	5.89	19.0	11.3	4.97	1.36	7.77	-	0.419	0.125	0.174	0.191	-	-	14	<5	<0.005	-	0.331	0.095	-	70	0.85	40
/01/80	-	67.0	6.01	14.0	3.0	2.53	1.43	6.58	-	0.425	0.583	0.014	0.432	-	-	10	5	0.993	-	0.588	0.129	-	100	0.65	13
/01/80	-	134.8	5.69	10.5	2.4	2.47	0.99	48.3	-	0.077	0.087	0.261	0.128	-	-	27	9	0.548	-	0.455	0.056	-	5	1.0	21
/08/81	206	350	8.01	119.3	123	40.1	4.64	10.3	1.15	0.04	0.01	-	-	-	-	33	16	0.012	0.002	-	-	-	-	-	-
/08/81	142	-	6.76	42.4	25	14.3	1.62	-	-	-	-	-	-	-	-	36	-	-	-	-	-	-	-	-	-
/08/81	209	370	6.47	48.4	27	14.6	2.83	43.0	1.84	0.02	0.12	-	-	-	-	74	18	5.19	0.003	-	-	-	-	-	-
/04/81	54	70	5.71	11.4	3	2.3	1.38	7.73	0.60	0.01	0.04	0.06	<0.01	<0.01	<0.005	12	-	1.79	<0.005	<0.005	0.042	0.135	5	-	-
/04/81	54	80	5.74	12.1	7	2.4	1.45	9.39	0.42	<0.01	0.02	0.02	<0.01	<0.01	<0.005	15.1	-	0.010	<0.005	<0.005	0.042	0.121	5	-	3
/04/81	48	60	5.39	11.8	3	3.1	0.96	5.58	0.65	<0.01	0.03	0.07	0.01	<0.01	<0.005	8.0	-	1.03	<0.005	0.132	0.030	0.130	5	-	4
/04/81	186	300	4.60	50.6	<1	15.2	2.54	23.8	5.80	<0.01	1.19	0.48	0.20	<0.01	<0.005	41	-	13.61	<0.005	0.035	0.032	0.135	5	-	-
/04/81	68	100	5.23	12.3	1	1.9	1.78	12.8	0.68	0.01	0.05	0.11	0.41	<0.01	<0.005	30	-	3.78	<0.005	0.106	0.035	0.135	5	-	7

Well Name	Location	Bedrock Unit	Well Type[3]	Well Depth (m)	Date Sampled D/M/Y	Tot. Diss. Solids (mg/L)	Specific Conduct. (mmhos/cm)	pH (units)	Hardness (mg/L) ($CaCO_3$)	Alkalinity (mg/L) ($CaCO_3$)	CATIONS Calcium (mg/L)	Magnes. (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Iron (mg/L)	Mangan. (mg/L)	Copper (mg/L)	Zinc (mg/L)	Lead (mg/L)	Ca (mg/L)
Municipal No.3	Admiral's Beach[1]	Drook Fmn.	B	12.9	10/02/80	135	256.1	8.30	112.9	94.1	24.8	12.36	10.8	-	<0.01	0.046	-	-	<0.01	
Municipal No.5	Admiral's Beach[1]	"	B	19.4	22/02/80	143	252.7	8.26	118.8	101.1	31.1	9.94	10.50	-	0.036	0.068	-	-	-	
Domestic-00041	Bauline	Harbour Main	B	36.	15/06/79	86	127.0	6.46	46.4	42.6	12.8	3.27	6.95	0.808	0.443	0.025	-	-	-	
Domestic-00049	Bauline	Group/Holyrood	B	6.	15/06/79	1128	-	6.85	331.4	69.8	100.7	19.43	-	-	-	-	-	-	-	
Domestic-00050	Bauline	Granite	B	63.	15/06/79	1077	204.9	6.31	139.9	28.6	46.3	5.59	353.1	7.563	0.296	0.394	-	-	-	
Municipal No.3	Bell Island (Wabana)	Bell Island	B	48.	09/12/76	-	442.6	7.96	155.3	145.4	46.5	9.40	-	-	0.067	0.238	<0.01	0.021	-	
Municipal-Davidson Ave.	Bell Island (Wabana)	and	B	103.3	09/12/76	-	373.7	7.80	156.5	129.8	51.9	6.28	-	-	0.438	0.158	<0.01	0.018	-	
Municipal-Woods Ave.	Bell Island (Wabana)	Wabana Groups	B	165.5	09/12/76	-	398.8	8.42	111.1	121.8	33.6	6.55	-	-	0.129	0.043	<0.01	0.071	-	
Municipal-Downing St.	Bell Island (Wabana)		B	64.	09/12/76	-	449.2	8.16	103.2	116.2	31.0	6.15	-	-	0.079	0.129	<0.01	0.029	-	
Municipal	Bell Island (Wabana)		B	121.9	09/12/76	-	413.1	8.86	91.7	141.0	13.39	1.63	-	-	0.112	0.031	<0.01	<0.01	-	
Municipal-Main St.	Bell Island (Wabana)		B	190.5	09/12/76	-	367.4	7.86	113.5	146.2	38.01	4.23	-	-	0.523	0.117	<0.01	0.021	-	
Municipal-Railroad St.	Bell Island (Wabana)		B	64.	09/12/76	-	362.1	7.96	138.1	115.4	44.09	5.60	-	-	2.066	0.650	<0.01	0.033	-	
Municipal-East No. 1	Bell Island (Wabana)	"	B	24.4	09/12/76	-	416.9	6.28	109.3	52.0	32.79	6.55	-	-	0.135	0.337	0.100	0.037	-	
Municipal- Bridal Ave.	Bell Island (Wabana)		B	-	09/12/76	-	458.5	7.70	163.2	118.4	55.68	5.56	-	-	0.088	0.595	<0.01	0.021	-	
Domestic	Bell Island		B	27.4	03/11/80	203	380.	7.66	129.2	100.	38.98	7.39	23.85	-	0.48	0.33	0.02	0.20	-	
Municipal	Blaketown[1]	Quidi Vidi Fmn.	B	69.	10/01/83	220	190	8.50	17.9	86.0	5.10	1.02	29.00	-	0.28	0.02	-	-	<0.01	
Municipal	Calvert[1]	Drook-Mistaken Pt.	B	36.5	19/05/82	-	50	4.58	4.9	<1	0.69	0.58	-	-	0.38	0.05	0.02	<0.01	-	
Domestic (?)	Calvert		?	-	22/05/81	-	60	6.20	8.9	2	1.53	1.15	-	-	0.14	0.03	<0.01	<0.01	-	
Domestic (?)	Calvert		?	-	?	-	80	4.63	10.1	<1	1.67	1.28	-	-	0.21	0.14	<0.01	<0.01	-	
Domestic (1921)	Chamberlains	?	?	-	12/07/79	908	-	8.96	48.4	111.8	17.02	1.42	-	-	-	-	-	-	-	
Domestic (1920)	Chamberlains	?	?	-	12/07/79	144	171.7	7.20	61.7	45.6	18.27	3.74	10.07	0.715	0.034	0.335	-	-	-	
Domestic-00347	Flat Rock	Drook Fmn. ?	?	-	24/08/81	269	-	8.11	108.7	64	30.4	7.96	-	-	-	-	-	-	-	
Domestic-00209	Foxtrap	Drook-Mistaken Pt.	B	17.4	08/08/80	155	203.7	7.10	77.3	71.0	25.05	2.97	9.68	0.74	0.60	0.790	-	-	-	
Domestic-00333	Harbour Main	Drook Fmn.	B	31.	08/08/80	140	80.1	7.28	74.5	76.7	26.80	1.83	9.43	-	0.06	<0.01	-	-	-	
Domestic-00337	Harbour Main	Gaskiers Fmn.	B	18.6	08/08/80	277	-	6.78	84.2	85.4	28.10	3.42	-	-	-	-	-	-	-	
Domestic-00319	Holyrood	Drook Fmn.	B	14.4	08/08/80	111	308.5	7.95	67.9	86.6	24.44	1.65	39.81	0.89	0.07	<0.01	-	-	-	
Domestic-00322	Holyrood	Harbour Main (1c)	B	-	08/08/80	86	106.4	6.67	31.6	28.6	10.22	1.43	7.75	0.42	0.08	<0.01	-	-	-	
Domestic-00327	Holyrood	Harbour Main (1b/c)	?	-	08/08/80	573	781.4	7.16	237.5	154.1	84.24	5.64	61.36	1.16	1.03	1.17	-	-	-	
Domestic-00292	Indian Pond	Bonavista, Smith Pt.	B	72.	08/08/80	38	-	7.22	65.4	26.1	22.08	2.49	-	-	-	-	-	-	-	
Institutional-00298	Indian Pond	Harbour Main(1a)	B	34.5	08/08/80	83	281.2	6.99	65.9	58.6	23.23	1.90	27.63	1.39	0.05	0.01	-	-	-	
Domestic-00309	Indian Pond	Harbour Main(1a)	B	18.	08/08/80	70	159.2	7.12	58.8	50.7	18.87	2.31	6.64	0.70	0.10	0.01	-	-	-	
Domestic-00407A	Logy Bay	Cuckold Fmn.	B	16.5	24/08/81	158	200	6.55	32.4	23	8.57	2.65	17.5	1.02	0.03	0.02	-	-	-	
Domestic-00427	Logy Bay	Quidi Vidi Fmn.	?	-	24/08/81	118	160	6.58	48.6	39	13.1	3.49	11.7	1.20	0.45	0.41	-	-	-	
Municipal-1	O'Donnells[1]	Drook Fmn.	B	93.	05/01/81	161	320	8.28	49.8	81.7	13.39	3.45	48.2	-	1.16	0.05	-	-	<0.01	
Domestic-00051	Portugal Cove	Harbour Main, Gaskiers Fmn.	B	154.	29/06/79	155	251.6	8.37	57.1	70.8	20.03	0.84	29.72	0.430	0.014	0.087	-	-	-	
Domestic-00060	Portugal Cove	Drook Fmn.	?	-	29/06/79	78	114.1	6.4	22.0	14.2	6.51	1.36	10.43	0.822	0.047	0.025	-	-	-	
Domestic-00076	Portugal Cove	Harbour Main, Mall Bay, Drook Fmn.	B	50.	29/06/79	275	423.3	9.39	14.6	48.2	5.65	0.08	77.75	0.848	0.043	0.01	-	-	-	
Domestic-00078	Portugal Cove	"	B	-	29/06/79	44	75.8	5.78	8.5	3.6	1.81	0.92	9.73	0.451	0.053	0.015	-	-	-	
Domestic-00063	Portugal Cove	"	B	72.	29/06/79	169	-	8.25	91.2	93.4	31.46	3.08	-	-	-	-	-	-	-	
Domestic-00068	Portugal Cove	"	B	73.8	29/06/79	156	-	8.16	56.2	73.6	21.15	0.82	-	-	-	-	-	-	-	
Domestic #4	Pouch Cove	Drook Fmn.	B	60.	13/06/79	473	570	7.75	388.8	103	142.6	7.94	23.24	0.938	0.025	<0.01	-	-	-	
Domestic #24	Pouch Cove	"	B	92.5	09/06/79	141	272	7.62	76.8	87.6	26.9	2.33	21.17	0.846	0.035	0.031	-	-	-	
Domestic 25	Pouch Cove	"	B	51.	09/06/79	251	-	5.70	51.2	13.6	14.8	3.46	-	-	-	-	-	-	-	
Municipal-Capp. North	Renews-Cappahayden[1]	?	B	62.2	19/08/83	-	-	-	-	-	-	-	-	-	1.24	0.51	-	-	-	
Domestic-00297	Seal Cove	Chamberlains Brook	B	25.2	08/08/80	201	241.4	6.44	53.5	16.6	11.31	6.06	21.69	1.10	0.17	0.01	-	-	-	
Domestic-00353	Shoe Cove	Drook Fmn.	B	-	24/08/81	78	120	6.93	23.2	13	5.97	1.99	11.3	0.57	0.05	<0.01	-	-	-	
Domestic #12	St. Phillips	Harbour Main Group	?	-	10/07/79	64	1181.8	7.13	332.0	50.2	128.63	2.48	80.28	0.590	0.300	0.020	-	0.058	-	
Domestic (96)	Thorburn Road	Ablation Moraine	O	-	21/01/80	-	94.1	5.24	14.8	1	3.96	1.07	6.21	-	0.052	0.232	0.01	0.015	-	
Domestic (97)	Thorburn Road	"	O	-	21/01/80	-	87.3	5.89	19.0	11.3	4.97	1.36	7.77	-	0.419	0.125	0.174	0.191	-	
Domestic (98)	Thorburn Road	"	O	-	21/01/80	-	67.0	6.01	14.0	3.0	2.53	1.43	6.58	-	0.425	0.583	0.014	0.432	-	
Domestic (99)	Thorburn Road	"	O	-	21/01/80	-	134.8	5.69	10.5	2.4	2.47	0.99	48.3	-	0.077	0.087	0.261	0.128	-	
Domestic-00365	Torbay	St. John's or	B	97.5	24/08/81	206	350	8.01	119.3	123	40.1	4.64	10.3	1.15	0.04	0.01	-	-	-	
Domestic-00383	Torbay	Signal Hill Groups	B	30.5	24/08/81	142	-	6.76	42.4	25	14.3	1.62	-	-	-	-	-	-	-	
Domestic-00413	Torbay	(12,13,14,or16)	B	-	24/08/81	209	370	6.47	48.4	27	14.6	2.83	43.0	1.84	0.02	0.12	-	-	-	
Observation-NPB #1	Torbay[2]	Stoney Till	O	6.1	23/04/81	54	70	5.71	11.4	3	2.3	1.38	7.73	0.60	0.01	0.04	0.06	<0.01	<0.01	<0
Observation-NPB #2	Torbay[2]	"	O	4.0	23/04/81	54	80	5.74	12.1	7	2.4	1.45	9.39	0.42	<0.01	0.02	0.02	<0.01	<0.01	<0
Observation-NPB #3	Torbay[2]	"	O	6.2	23/04/81	48	60	5.39	11.8	3	3.1	0.96	5.58	0.65	<0.01	0.03	0.07	0.01	<0.01	<0
Observation-NPB #4	Torbay[2]	"	O	3.8	23/04/81	186	300	4.60	50.6	<1	15.2	2.54	23.8	5.80	<0.01	1.19	0.48	0.20	<0.01	<0
Observation-NPB #5	Torbay[2]	"	O	5.4	23/04/81	68	100	5.23	12.3	1	1.9	1.78	12.8	0.68	0.01	0.05	0.11	0.41	<0.01	<0
Observation-Site E(Sh.)	Waterfd. River Basin[2]	Stoney till	O	-	12/10/82	-	90.	6.8	31.1	22.5	10.	1.5	6.6	0.7	0.12	0.01	<0.002	0.019	0.002	
Observation-Site E(Deep)	Waterfd. River Basin[2]	Stoney till	O	-	12/10/82	-	165.	7.7	93.1	69.1	33.	2.6	8.2	0.5	1.3	0.02	<0.002	0.005	<0.002	

Note 1 - Samples collected during well yield test
Note 2 - Special project, Dept. of Environment.
Note 3 - B = Bedrock well; O = Overburden well
Note 4 - Fmn. = Formation; Sh. = Shallow

Table 5.1 Summary of water quality data.

ed	Tot. Diss. Solids (mg/L)	Specific Conduct. (mmhos/cm)	pH (units)	Hardness (mg/L) ($CaCO_3$)	Alkalinity (mg/L) ($CaCO_3$)	CATIONS										ANIONS							Apparent Colour (TCU)	Turbid. (JTU)	COD (mg/L)
						Calcium (mg/L)	Magnes. (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Iron (mg/L)	Mangan. (mg/L)	Copper (mg/L)	Zinc (mg/L)	Lead (mg/L)	Cadmium (mg/L)	Chlor. (mg/L)	Sulf. (mg/L)	Nitrate N(mg/L)	Nitrite N(mg/L)	Kjeldahl N(mg/L)	Phos. (mg/L)	Fluor. (mg/L)			
/80	135	256.1	8.30	112.9	94.1	24.8	12.36	10.8	-	<0.01	0.046	-	-	<0.01	-	16	9	-	-	0.263	-	-	<5	0.43	-
/80	143	252.7	8.26	118.8	101.1	31.1	9.94	10.50	-	0.036	0.068	-	-	-	-	14	9	-	-	0.286	-	-	<5	0.33	-
/79	86	127.0	6.46	46.4	42.6	12.8	3.27	6.95	0.808	0.443	0.025	-	-	-	-	20	1	<0.005	-	-	-	-	-	-	-
/79	1128	-	6.85	331.4	69.8	100.7	19.43	-	-	-	-	-	-	-	-	423	-	-	-	-	-	-	-	-	-
/79	1077	204.9	6.31	139.9	28.6	46.3	5.59	353.1	7.563	0.296	0.394	-	-	-	-	593	29	4.683	-	-	-	-	-	-	-
/76	-	442.6	7.96	155.3	145.4	46.5	9.40	-	-	0.067	0.238	<0.01	0.021	-	0.01	-	-	0.551	-	0.125	0.070	-	7.5	0.16	3.36
/76	-	373.7	7.80	156.5	129.8	51.9	6.28	-	-	0.438	0.158	<0.01	0.018	-	0.01	-	-	0.056	-	0.440	0.071	-	10.	1.15	0.46
/76	-	398.8	8.42	111.1	121.8	33.6	6.55	-	-	0.129	0.043	<0.01	0.071	-	<0.01	-	-	0.026	-	0.331	0.077	-	<5	0.40	<0.2
/76	-	449.2	8.16	103.2	116.2	31.0	6.15	-	-	0.079	0.129	<0.01	0.029	-	<0.01	-	-	0.026	-	0.374	0.056	-	<5	0.16	7.07
/76	-	413.1	8.86	91.7	141.0	13.39	1.63	-	-	0.112	0.031	<0.01	<0.01	-	<0.01	-	-	0.021	-	0.470	0.108	-	5	0.40	<0.2
/76	-	367.4	7.86	113.5	146.2	38.01	4.23	-	-	0.523	0.117	<0.01	0.021	-	<0.01	-	-	0.008	-	0.174	0.066	-	15	0.60	<0.2
/76	-	362.1	7.96	138.1	115.4	44.09	5.60	-	-	2.066	0.650	<0.01	0.033	-	<0.01	-	-	0.055	-	0.075	0.122	-	10	0.75	8.62
/76	-	416.9	6.28	109.3	52.0	32.79	6.55	-	-	0.135	0.337	0.100	0.037	-	0.01	-	-	2.220	-	0.033	0.060	-	<5	0.40	2.19
/76	-	458.5	7.70	163.2	118.4	55.68	5.56	-	-	0.088	0.595	<0.01	0.021	-	<0.01	-	-	0.120	-	0.101	0.062	-	5	0.18	15.64
/80	203	380.	7.66	129.2	100.	38.98	7.39	23.85	-	0.48	0.33	0.02	0.20	-	<0.005	43	22	0.300	-	-	0.020	-	5	0.76	9.
/83	220	190	8.50	17.9	86.0	5.10	1.02	29.00	-	0.28	0.02	-	-	<0.01	-	9.49	-	<0.002	-	-	-	-	-	17	-
/82	-	50	4.58	4.9	<1	0.69	0.58	-	-	0.38	0.05	0.02	<0.01	-	<0.005	-	-	0.013	-	0.022	0.016	-	70	0.48	37
/81	-	60	6.20	8.9	2	1.53	1.15	-	-	0.14	0.03	<0.01	<0.01	-	<0.005	-	-	0.015	-	0.299	0.021	-	50	0.64	18
	-	80	4.63	10.1	<1	1.67	1.28	-	-	0.21	0.14	<0.01	<0.01	-	<0.005	-	-	0.044	-	0.44	0.015	-	20	0.62	18
/79	908	-	8.96	48.4	111.8	17.02	1.42	-	-	-	-	-	-	-	-	302	-	-	-	-	-	-	-	-	-
/79	144	171.7	7.20	61.7	45.6	18.27	3.74	10.07	0.715	0.034	0.335	-	-	-	-	18	36	<0.005	0.002	-	-	-	-	-	-
/81	269	-	8.11	108.7	64	30.4	7.96	-	-	-	-	-	-	-	-	86	-	-	-	-	-	-	-	-	-
/80	155	203.7	7.10	77.3	71.0	25.05	2.97	9.68	0.74	0.60	0.790	-	-	-	-	15	16	<0.005	<0.005	-	-	-	-	-	-
/80	140	80.1	7.28	74.5	76.7	26.80	1.83	9.43	-	0.06	<0.01	-	-	-	-	12	10	0.686	<0.005	-	-	-	-	-	-
/80	277	-	6.78	84.2	85.4	28.10	3.42	-	-	-	-	-	-	-	-	64	-	-	-	-	-	-	-	-	-
/80	111	308.5	7.95	67.9	86.6	24.44	1.65	39.81	0.89	0.07	<0.01	-	-	-	-	35	12	0.017	<0.005	-	-	-	-	-	-
/80	86	106.4	6.67	31.6	28.6	10.22	1.43	7.75	0.42	0.08	<0.01	-	-	-	-	13	<5	0.413	<0.005	-	-	-	-	-	-
/80	573	781.4	7.16	237.5	154.1	84.24	5.64	61.36	1.16	1.03	1.17	-	-	-	-	132	20	0.026	<0.005	-	-	-	-	-	-
/80	38	-	7.22	65.4	26.1	22.08	2.49	-	-	-	-	-	-	-	-	27	-	-	-	-	-	-	-	-	-
/80	83	281.2	6.99	65.9	58.6	23.23	1.90	27.63	1.39	0.05	0.01	-	-	-	-	44	6	0.738	<0.005	-	-	-	-	-	-
/80	70	159.2	7.12	58.8	50.7	18.87	2.31	6.64	0.70	0.10	0.01	-	-	-	-	11	11	0.026	<0.005	-	-	-	-	-	-
/81	158	200	6.55	32.4	23	8.57	2.65	17.5	1.02	0.03	0.02	-	-	-	-	36	12	1.28	0.001	-	-	-	-	-	-
/81	118	160	6.58	48.6	39	13.1	3.49	11.7	1.20	0.45	0.41	-	-	-	-	20	8	0.252	0.001	-	-	-	-	-	-
/81	161	320	8.28	49.8	81.7	13.39	3.45	48.2	-	1.16	0.05	-	-	<0.01	-	1	18	0.336	-	-	-	-	5	4.4	-
/79	155	251.6	8.37	57.1	70.8	20.03	0.84	29.72	0.430	0.014	0.087	-	-	-	-	26	28	0.005	0.001	0.116	-	-	-	-	-
/79	78	114.1	6.4	22.0	14.2	6.51	1.36	10.43	0.822	0.047	0.025	-	-	-	-	25	12	0.578	<0.001	0.073	-	-	-	-	-
/79	275	423.3	9.39	14.6	48.2	5.65	0.08	77.75	0.848	0.043	0.01	-	-	-	-	27	215	0.012	0.002	0.091	-	-	-	-	-
/79	44	75.8	5.78	8.5	3.6	1.81	0.92	9.73	0.451	0.053	0.015	-	-	-	-	22	6	0.223	<0.001	0.138	-	-	-	-	-
/79	169	-	8.25	91.2	93.4	31.46	3.08	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-
/79	156	-	8.16	56.2	73.6	21.15	0.82	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-
/79	473	570	7.75	388.8	103	142.6	7.94	23.24	0.938	0.025	<0.01	-	-	-	-	82	27	7.06	-	-	-	-	-	-	-
/79	141	272	7.62	76.8	87.6	26.9	2.33	21.17	0.846	0.035	0.031	-	-	-	-	31	8	0.129	-	-	-	-	-	-	-
/79	251	-	5.70	51.2	13.6	14.8	3.46	-	-	-	-	-	-	-	-	81	-	-	-	-	-	-	-	-	-
/83	-	-	-	-	-	-	-	-	-	1.24	0.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-
/80	201	241.4	6.44	53.5	16.6	11.31	6.06	21.69	1.10	0.17	0.01	-	-	-	-	55	0.563	<0.005	-	-	-	-	-	-	-
/81	78	120	6.93	23.2	13	5.97	1.99	11.3	0.57	0.05	<0.01	-	-	-	-	20	0.405	0.002	-	-	-	-	-	-	-
/79	64	1181.8	7.13	332.0	50.2	128.63	2.48	80.28	0.590	0.300	0.020	-	0.058	-	-	284	237	0.021	<0.001	-	-	-	-	-	-
/80	-	94.1	5.24	14.8	1	3.96	1.07	6.21	-	0.052	0.232	0.01	0.015	-	-	10	11	2.57	-	0.311	0.062	-	5	0.50	11
/80	-	87.3	5.89	19.0	11.3	4.97	1.36	7.77	-	0.419	0.125	0.174	0.191	-	-	14	<5	<0.005	-	0.331	0.095	-	70	0.85	40
/80	-	67.0	6.01	14.0	3.0	2.53	1.43	6.58	-	0.425	0.583	0.014	0.432	-	-	10	5	0.993	-	0.588	0.129	-	100	0.65	13
/80	-	134.8	5.69	10.5	2.4	2.47	0.99	48.3	-	0.077	0.087	0.261	0.128	-	-	27	9	0.548	-	0.455	0.056	-	5	1.0	21
/81	206	350	8.01	119.3	123	40.1	4.64	10.3	1.15	0.04	0.01	-	-	-	-	33	16	0.012	0.002	-	-	-	-	-	-
/81	142	-	6.76	42.4	25	14.3	1.62	-	-	-	-	-	-	-	-	36	-	-	-	-	-	-	-	-	-
/81	209	370	6.47	48.4	27	14.6	2.83	43.0	1.84	0.02	0.12	-	-	-	-	74	18	5.19	0.003	-	-	-	-	-	-
/81	54	70	5.71	11.4	3	2.3	1.38	7.73	0.60	0.01	0.04	0.06	<0.01	<0.01	<0.005	12	-	1.79	<0.005	<0.005	0.042	0.135	5	-	-
/81	54	80	5.74	12.1	7	2.4	1.45	9.39	0.42	<0.01	0.02	0.02	<0.01	<0.01	<0.005	15.1	-	0.010	<0.005	<0.005	0.042	0.121	5	-	3
/81	48	60	5.39	11.8	3	3.1	0.96	5.58	0.65	<0.01	0.03	0.07	0.01	<0.01	<0.005	8.0	-	1.03	<0.005	0.132	0.030	0.130	5	-	4
/81	186	300	4.60	50.6	<1	15.2	2.54	23.8	5.80	<0.01	1.19	0.48	0.20	<0.01	<0.005	41	-	13.61	<0.005	0.035	0.032	0.135	5	-	-
/81	68	100	5.23	12.3	1	1.9	1.78	12.8	0.68	0.01	0.05	0.11	0.41	<0.01	<0.005	30	-	3.78	<0.005	0.106	0.035	0.135	5	-	7
/82	-	90.	6.8	31.1	22.5	10.	1.5	6.6	0.7	0.12	0.01	<0.002	0.019	0.002	-	7.1	7.6	0.90	-	-	0.005	-	5	2.7	-
/82	-	165.	7.7	93.1	69.1	33.	2.6	8.2	0.5	1.3	0.02	<0.002	0.005	<0.002	-	8.5	18.5	1.95	-	-	0.007	-	5	11.	-